2016

An Analysis Of Agricultural Decision-Making For Phosphorus Runoff Reduction In The State Of Vermont

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AN ANALYSIS OF AGRICULTURAL DECISION-MAKING FOR PHOSPHORUS RUNOFF REDUCTION IN THE STATE OF VERMONT

A Thesis Presented

by

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to

The Faculty of the Graduate College

of

The University of Vermont

In Partial Fulfillment of the Requirements
For the Degree of Master of Science
Specializing in Community Development and Applied Economics

October, 2016

Defense Date: April 25, 2016
Thesis Examination Committee

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ABSTRACT

Eutrophication, stimulated by phosphorous (P) runoff from landscapes, compromises water quality and can have long-term impacts on the aesthetics, recreation, property values, and drinkability of bodies of water around the world. In the State of Vermont, efforts are underway to control the amount of P entering Lake Champlain per standards set forth in the Federal Clean Water Act. Agriculture has been identified as a major contributor to excess P in the waterways and will be managed according to Act 64, the Vermont Water Quality Act. The studies presented in this paper will introduce two independent methodologies proposed to aid in evaluating the farmer's willingness to implement pro-environmental practices, (1) determining farmer values towards implementation of best management practices to inform policy, and (2) creating a multifunctional sustainability prioritization scheme for dissemination of Clean Water Fund resources.

The Vermont Water Quality Act proposes Required Agricultural Practices (RAP) for agriculture in the State with a limited understanding of what the farming community desires from such a policy. This paper's first article titled, "Determining Farmer Values for Implementing Pro-Environmental Practices," analyzes twenty-four farmers and their associated values towards adopting pro-environmental practices for improved water quality. A hierarchical cluster analysis was used to segment farmers according to their adoption of best management practices on their farms. Further, a one-way analysis of variance (ANOVA) was conducted using dependent functional (quality), functional (price), and emotional, social, conditional, and epistemic variables to understand the variance between the segments. The results from this analysis illuminate farmer values. This information can be used to inform water quality policy, ecosystem service payments, communication strategy, and funding dissemination.

The Clean Water Fund was created to support the implementation of water quality initiatives in various sectors throughout the State of Vermont. The resources within the fund are limited; therefore careful prioritization of farms for outreach is essential. In the article titled, "Prioritizing Farms for Subsidies: A Multifunctional Approach," a prioritization methodology is presented using theory from the sustainable multifunctional agriculture literature. The sample includes vegetable, vegetable and meat, meat, and maple producers within the State. The diverse production types included in this study reflects the non-discriminatory—relating to production types—policies in Act 64. The study is limited by the exclusion of the dairy sector. Geographic Information Systems (GIS) software was used to map environmental practices on twelve farm landscapes to generate a spatial representation of environmental stewardship that was then translated into an environmental score. This environmental score was combined with social and economic data to prioritize farms based upon their multifunctional sustainability. This ranking methodology may be useful for the State of Vermont in determining the prioritization of Clean Water Fund resources using farm sustainability measurements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: PHOSPHORUS RUNOFF REDUCTION IN AGRICULTURE

1.1. Phosphorus as a Nutrient

Phosphorus (P) is a chemical element found naturally in phosphate based rock minerals and organic matter. It plays an important role in the development of the flora and fauna throughout the world. Each animal and plant cell contains around 1,000 to 2,000 mitochondria, known as the energy house for the organism. The mitochondria is responsible for the creation of the Adenosine Triphosphate (ATP) molecule that transfers energy, via the sun or food, into a form that can be processed by the organism. Triphosphate is an essential component of this molecule where the three phosphate atoms are connected and surrounded by oxygen atoms. The oxygen atoms are negatively charged and repel each other forming the energy in the molecule. When a phosphorus group is removed, along with the attached negatively charged oxygen atoms, the molecule is more stable and respective energy has been released. This is known as the conversion of ATP to Adenosine Diphosphate (ADP) the process that supplies both plants and animals with energy. With an adequate amount of phosphorus in the soil from which a plant is grown, the organism will be efficient at transferring the energy of the sun for seed development, plant growth, and maturity (Johnston, 2000). Likewise, when P is contained in an animal's food then the animal can better transfer energy from the oxidation process leading to proper functioning, development, and reproduction of the organism.

1.2. Phosphorus Use in Agriculture

Prior to industrialization, populations were able to subsist on agricultural production using P found naturally in soil, manure, and plant residues (Ashley et al., 2011). Ecological scale was achieved at this time as the ecosystem fully supported the animal and plant organisms of which depended on its functioning. With increases in populations and migrations of people to cities there became a demand for an increase in food production. The Green Revolution began in the mid twentieth century to increase the yields of crops using new technological advancements including innovative irrigation, the introduction of new management techniques, hybrid seed distribution, synthetic fertilizers, and the use of pesticides (Pingali, 2012). In this time period there was a focus on harnessing outside resources, including phosphorus from mineral reserves, to meet regional food production goals. The ability of the ecosystem to assimilate introduced nutrients was unknown at the time; only now is the ecological impact becoming known as science catches up with the technological advancements of the Green Revolution (Pingali, 2012; Evenson & Gollin, 2003; Vignieri, 2014).

1.2.1. Phosphorus and Eutrophication

Eutrophication is defined as the "Waters, soils, or habitats that are high in nutrients; in aquatic systems, associated with wide swings in dissolved oxygen concentrations and frequent algal blooms (Committee on Environment and Natural Resources, 2000)." Eutrophication can have long-term impacts on the recreation (Dodds, 2008), property values (Gibbs et al., 2002), aquatic food webs (Dodds, 2008) and drinkability (Liu et al., 2011) of waterbodies. To understand water eutrophication, stimulated by P runoff from landscapes, we must explore the bio-physical interactions of the mineral and the environment.

P exists both organically and inorganically in nature. In its organic structure it exists naturally in the form of manure or plant residue. Alternatively, the inorganic nutrient is extracted from mineral reserves throughout the world to be included in agricultural fertilizer. Manure contains a ratio of nitrogen, potassium, and phosphorus. In some instances, nutrient management programs targeting the effective application of one nutrient can lend to over-application of another nutrient contained in manure-intensive program (Parsons, 2016). For instance, when a farmer is using manure to fertilize fields, a focus on nitrogen could contribute to the over application of both potassium and phosphorus (Parsons, 2016). Using inorganic fertilizer inputs allows for the control of nutrient ratios, including the addition of potassium and nitrogen without phosphorus. This is an argument for the control of inorganic phosphorus over organic manure in fertilizing plants on farms. Although both nitrogen and phosphorus contribute to eutrophication, phosphorus has been determined to be a limiting factor, or a critical component in the eutrophication process (Schindler, 1974). Thus, a viable phosphorus management plan will aid in limiting eutrophication in bodies of water.

Excess P in agricultural fields is primarily caused by the over application of the mineral to agricultural soils (Childers et al., 2011). Plants do not have the capacity to absorb all the available nutrients found in the soil. The United Nations Food and

Agriculture Organization (FAO) concluded that about 15% to 30% of the P found in soil is actually absorbed by plants (Childers et al., 2011). They inferred that this low intake rate can be attributed to the suggested application rate being far in excess of what the plant actually needs. An excess amount of P in the soil is both an economic and environmental issue (Yadav et al., 1997; Smith et al., 1999). In the State of Vermont, optimum levels of soil nutrients for proper corn plant growth are Phosphorus (P) 4.1-7 ppm, Nitrogen (N) 101 – 130 ppm, and Potassium 51 – 100 ppm (The University of Vermont Extension, 2004). These levels of nutrients may be altered according to the crop of interest. Plants will not respond to excess phosphorus in the soil which can cause both economic and environmental hardship for the farmer and the downstream community, respectively. Economically, the over application of fertilizer to fields could cost a farmer between $3.50 and $22.50 per acre (Yadav et al., 1997). Environmentally, when nutrients are applied in excess of what the crop can assimilate, the nutrient content in the soil becomes concentrated and is sensitive to transport into local groundwater and surface water (Smith et al., 1999). Nutrient transport is dependent upon soil type as clay soils are more likely to hold nutrients than sandy soils. Therefore, there are both economic and environmental incentives to accomplishing the ecological scale of imported P in an ecosystem.

In this paper, we will explore types of policies that may be implemented to control the amount of P being added to landscapes and the amount of runoff from agricultural landscapes. Both successful and unsuccessful efforts to improve the health of waterbodies suffering from eutrophication can be studied throughout the world including those in Lake Taihu in China (Wang et al., 2006), the four largest lakes in Sweden (Wilander & Persson, 2001), and Lake Erie of the Great Lakes in the United States of America (Scavia et al., 2014). This aquatic issue is not isolated but impacts communities throughout the world.

1.3. Phosphorus Runoff Reduction Policy

Geographically, there have been many scales at which eutrophication has occurred and been managed. At the grandest scale of management is the European Sustainable Phosphorus Conference which met for the first time in March 2013 to formulate a plan to reduce the global demand for P, recycle the nutrient, and redefine the food system (Ulrich et al., 2013). The United States has developed the Clean Water Act and enforcement mechanisms to monitor the state of waterbodies within its boundaries. In the State of Vermont, the Clean Water Initiative has invested considerable funding in both the development of municipal wastewater treatment plants, the Ecosystem Restoration Program, and technical assistance to the farming community (Vermont Clean Water Initiative, 2014). Below is a summary of the efforts used to control water eutrophication in the United States of America and the State of Vermont.

1.3.1. Water Quality Regulation in the United States of America

The Federal Water Pollution Control Act was first enacted in the 1948 then amended in 1972 and the name changed to the Clean Water Act (CWA). This environmental initiative was intended to reduce the amount of untreated sewage being discharged into lakes, rivers and coastal waters. At the time the act was written, the public was becoming more interested in water quality as bacteria levels in the Hudson River were beyond the safe limit (Sañudo-Wilhelmy & Gill, 1999) and the Chesapeake Bay was becoming highly contaminated (Goldberg et al., 1978). The Clean Water Act (CWA) worked to resolve these issues by creating a regulation program for industrial, municipal and other facilities discharging into open water.

Regulation of standards set forth in the CWA controlled through a permitting process called the National Pollutant Discharge Elimination System (NPDES) which targets point sources of pollution. Point sources of pollution have been defined in the Clean Water Act in section 502(14) as "…any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture." From a management perspective, control of pollutants coming from a pipe is easier than regulating the non-point sources of pollution.

Non-point sources of contamination are described by the Clean Water Act as any source of pollution that does not meet the criteria set forth in the definition of point-source of contamination. General sources include land runoff and field drainage. This type of mobilization transports nutrients into lakes, rivers, wetlands, coastal waters and ground waters. These non-point sources are complex and difficult to regulate due to their flow through the environment instead of through a pipe like the point source pollutants.

The Environmental Protection Agency (EPA) enforces the CWA by monitoring the health of the nation's water by requiring each state to submit a Water Quality Assessment Report every two years under section 305(b) and 303(d) of the CWA. If bodies of water are deemed impaired according to the standards set forth by the CWA then the state must submit a Total Maximum Daily Load (TMDL) of the pollutant causing the impairment to the U.S. EPA. The TMDL is used to create an ecological scale in the body of water under consideration. By capping the amount of pollutants introduced to the system, regulations address both point source and non-point sources. If a body of water is deemed impaired then, the State must then create a plan that will foster meeting the target set forth by the TMDL.

There are many different land uses that contribute to P runoff, including agriculture, urban landscapes, roads, streambank erosion, and forest (Tetra Tech Inc., 2015). Although this paper focuses on non-point source nutrient runoff reduction from the agricultural sector; other sectors may be targeted for reduction in conglomeration for a greater impact.

1.3.2. Water Quality Regulation in the State of Vermont

In 2008, Vermont submitted data to the EPA on the health of 229,722 acres of lakes and reservoirs. Of the lakes and reservoirs surveyed, 61% were deemed impaired due to nutrient related causes (US EPA, 2011). Lake Champlain, the sixth largest waterbody in United States with territories in the states of Vermont and New York, USA and Quebec, Canada, was considered impaired due to nutrient related causes. The main source of this eutrophication is excess P in the waterways from both point sources and non-point sources of pollution. In 2002, the EPA issued a TMDL of P for Lake Champlain but this was legally challenged due to non-compliance and revoked in 2011 by the EPA. Since this time, the EPA has issued a new TMDL with higher standards. In 2015, The State of Vermont enacted Act 64 (H.35) which documents the activities that must happen within the state to reach the target TMDL of P entering Lake Champlain.

Act 64 is an act relating to improving the quality of state waters which focuses on P runoff reduction from non-point sources in agriculture as land under cultivation contributes to 41% of the P loading from the State of Vermont (Lake Champlain Basin Program, 2015). In order to achieve the standards set by the EPA the agricultural sector will have to undergo great reform.

1.4. Agricultural Production in the State of Vermont

There are many types of food produced on agricultural landscapes in the State of Vermont. As discussed in this section, agricultural land use is currently dominated by the dairy industry (USDA/NASS, 2015). Other productive land is used for maple, vegetable, orchards, and berries. Due to the dairy industries production processes and use of fertilizers and manure to improve forage growth (haylage, corn silage, grass silage, and greenchop), this sector is under considerable pressure to implement changes reducing the P flow from the farm. Dairy is not the only sector contributing to P pollution. Farm ownership transfer, nutrient build-up, and manure application on non-dairy corps can create legacy P in soils of various production types.

Dairy plays a large role in the agricultural economy of the state with sales in milk reaching 500 million which is responsible for about 65% of the agricultural sales in the state (USDA/NASS, 2015). The forage crops fed to dairy cows are generally grown within the state and comprise a large portion of the State's agricultural land use. These crops that support the Vermont dairy industry include hay and haylage, grass silage, and greenchop. Land designated for the dairy industry covers 900,000 acres or 80% of the total farm acreage in the State of Vermont (USDA Census of Agriculture, 2012).

Advancements in the Green Revolution, in organic and inorganic fertilizers allowed for farmers to create nutrient dense soils that fostered higher crop yields and subsequently increased milk production (Gollin, et al., 2005). Although this industry seems to have dominance over both the landscape and the agricultural economy in Vermont, it is not explicitly targeted in the new Vermont water quality initiatives.

Act 64 does not distinguish between different types of agricultural production, whether it be crops for animal feed or vegetable production. Instead, Act 64 has created sets of required agricultural practices (RAP) based solely on the size of the farm: the small farm operation (SFO), medium farm operation (MFO), and the large farm operation (LFO). Each type of farm operation will need to complete a certification declaring implementation of set RAP starting on July 1st, 2017. An additional permit is required for Concentrated Animal Feeding Operations (CAFO) that are either MFO or LFO in size. Proposed RAP's include a field-to-field 590 Nutrient Management Plan, vegetative buffer zone near surface water, animal mortality management, cover cropping, reduced tillage, exclusion of livestock from waterways, and an inspection within five years

(Vermont Agency of Agriculture, Food and Markets, 2015). The SFO's must complete a required education course for farmers and annually submit a report of compliance to the State of Vermont.

It is inferred from Act 64 that a farm will be considered a critical source area of P if their 590 Nutrient Management Plan reports large concentrations of minerals in farm soils. If the Vermont Agency of Agriculture Food & Markets deems a farm a critical source of P runoff then they have the authority to require implementation of specific best management practices (BMP) that are necessary to control runoff from the farm, this is beyond the requirements of the certification. The identification of suitable BMPs will happen during a farm inspection. If a BMP is selected for application on the farm, then the Secretary of Agriculture will advise the farmer on financial resources available to them for implementation. Funding can come from several sources although the Vermont Clean Water Fund may be the most accessible to farmers. The Secretary of Agriculture will re-evaluate a priority ranking system every year for small farms in accordance with the water quality benefit of the farm to the State of Vermont. As mentioned before, Act 64 does not discriminate between production types and research is suggesting that P accumulation can occur on different types of production fields or be built up in the soils before the farm was transferred to alternative production systems.

The literature suggests that P is prone to accumulating on land used for vegetable production (Chan et al., 2007; Zhang et al., 2003). Most of the research on this topic comes out of Sydney, Australia where vegetable crops in metropolitan areas have been used to supply the city with fresh produce (Chan et al., 2007). The study analyzed the differences in P levels between vegetable farms and unfarmed land. Chan (2007) concluded by recognizing a significant accumulation of minerals, including P, on vegetable farms. A similar study was conducted in China that examined the levels of P in soils under plastic greenhouses in comparison to soils under open cultivation in fields (Wang et al., 2015). The study found that soils under greenhouse cultivation accumulated P at a more extreme rate than the vegetable fields under open cultivation.

P build-up on vegetable soils in the State of Vermont was investigated by soil test results from a randomized sample of forty-eight vegetable farms. Of these farms, twenty-three reported high or excessive levels of P. That is approximately 48% of the samples included in this independent study (Bradshaw, 2016). Therefore, we can predict that vegetable production in the State of Vermont may be contributing to P runoff. As mentioned previously, this may be a product of either over application or conversion of fields with high concentrations of P to vegetable production. We are unsure whether the P buildup in these soils is from manure or fertilizer use.

Dairy farm closings have been fostered by volatile milk prices and the rising costs of inputs (Vermont Farm to Plate, 2013). Between 1997 and 2007 the number of dairy farms operating on 260 to 999 acres of land decreased from 1,014 farms to 630 farms (Vermont Farm to Plate, 2013). During this same time period, small farms operating under 59 acres of land grew by 319 farms (U.S.D.A. Census of Agriculture, 2012). In the years after the medium-sized farm exodus, milk prices plummeted due to the recession in 2008, the price of milk fell from $20.62/cwt in 2007 to just under $13.82/cwt in 2009 (Gould, 2016). Beyond the consolidation of the industry and the sudden price fluctuations of milk, the farming population is aging. The average age of farmers in Vermont is 57.3 years (Kosakowski, 2012). The age of principal farm operators suggests a future transformation of the agricultural sector in the State of Vermont which may lend itself to high rates of farm turnover. Farms may be transferred out of dairy and into vegetable while retaining current accumulations of nutrients in the soils from the prior use. Regulating all farms regardless of their production may incur greater watershed benefits due to legacy P before transitions and research indicating P accumulation occurs on fields under vegetable cultivation.

Through the certification process, the State of Vermont will collect information on nutrient levels through the field-to-field 560 Nutrient Management Plan. If a farm is considered to have excess amounts of P in their soils then state regulators will identify BMPs that will best control runoff from the farm and alleviate P in the soils. After this process is complete, a prioritization of the farms considered critical sources of P will be formulated by the Secretary of Agriculture. Chapter two of this paper will use systems theory to analyze the flow of P into the system and places of intervention that may lead to P reduction.

CHAPTER 2: STRATEGIES TO REDUCE PHOSPHORUS RUNOFF IN AGRICULTURE

In this section, we will review the types of intervention strategies that can be used to control the amount of phosphorus (P) inputs into Lake Champlain. Once again, other land uses contribute to phosphorus runoff other than agriculture. In addition, Lake Champlain is an example of one of many bodies of water in the State of Vermont that could be targeted for reduced P loads. Systems analysis will be used to illustrate the intervention points that may be used to decrease P runoff into Vermont waterways..

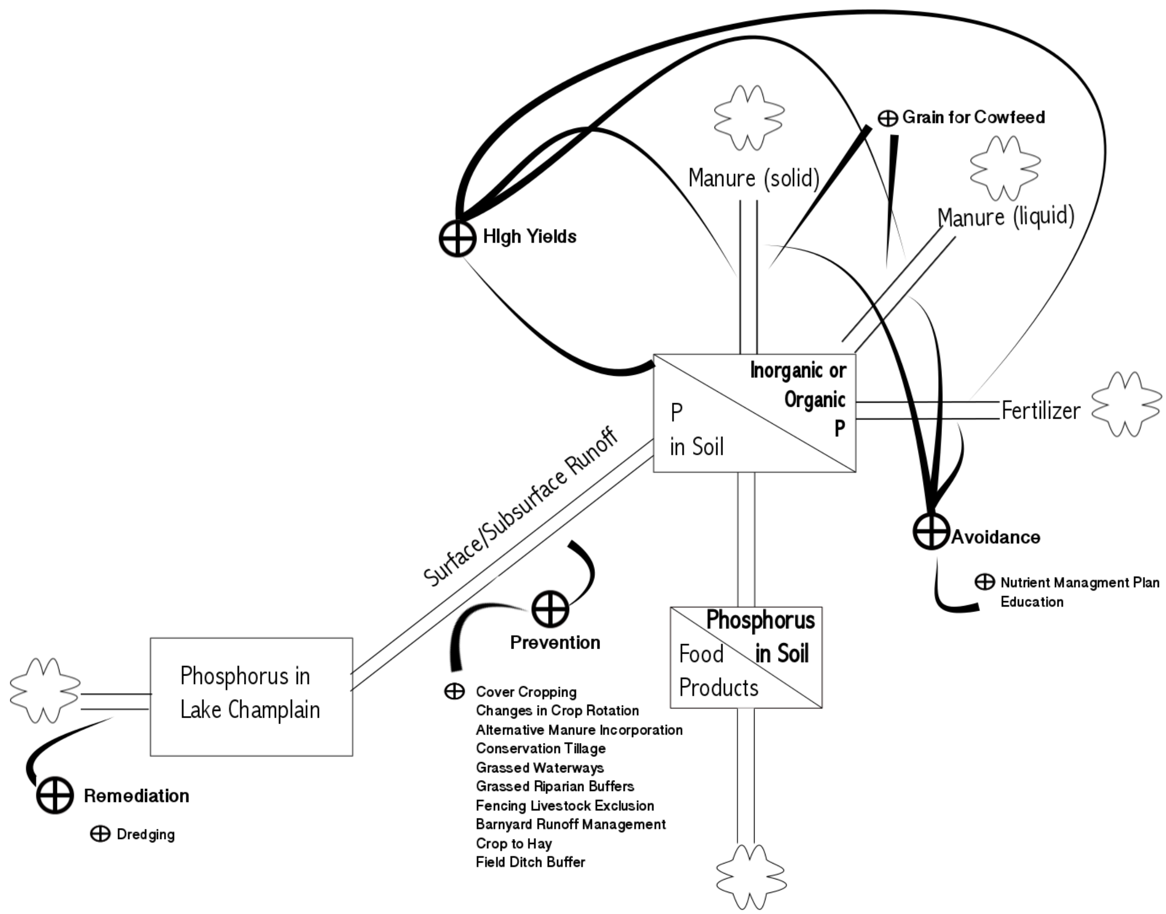

Figure 1: Brown (2016) System Overview of Phosphorus Reduction Strategies

Figure 1 presents an example of a system stock-flow diagram applied to the agricultural loading of P. This method of analyzing the inflows and outflows of P in an agricultural system has been used in other studies (Li et al., 2010; Ott & Rechberger, 2012; Suh & Yee, 2011). The agricultural system depicted in Figure 1 is a simplified version from Suh and Yee (2011). Figure 1 illustrates manure and fertilizer as inflows, P stock on the farm, and P flow from farms to Lake Champlain from surface and subsurface runoff. Manure may be recycled on the farm. In this system there is a perceived positive feedback loop between the stock of P on the farm and increases in crop yield. This perception incentivizes farmers to add more P onto their fields despite being in excess of the plants uptake. In addition, interception points are located along the inflow-outflow channels. Let it be known, that this system is very complex and the model presented does not account for a majority of the complexities that may arise.

The intervention points are defined as thus; (1) to *avoid* or limit the amount of P entering the system, (2) to *prevent* P already introduced into the system from having a negative impact on the environment, or (3) to *remediate* the contamination by removing it from the system through extraction or fixation in a stable stock (Buda et al., 2012). These categories will be used to describe places of intervention for the best management practices introduced by Tetra Tech ARD, Inc.

In 2015 Tetra Tech ARD, Inc. was hired by the State of Vermont to create a BMP Scenario Tool for presentation to the Environmental Protection Agency (Tetra Tech Inc., 2015). This tool used a suite of agricultural best management practices, associated runoff reduction efficiencies, and proprietary formulas to predict the amount of feasible runoff reduction the State could achieve after implementing the agricultural best management practices. Table 1 lists the BMPs presented in this paper according to where they intervene in the P system.

Table 1: BMPs by Intervention Place in Phosphorus System

Best Management Practice	Description	Place of Intervention
Cover Cropping	Establishing a seasonal cover on annual cropland for soil erosion reduction and conservation purposes. Cover cropping would consist of a crop of winter rye or other herbaceous plants.	Prevention
Changes in Crop Rotation	Standard rotations. For example, rotations of corn to hay and rotations of corn to soybean.	Prevention
Alternative Manure Incorporation	Applying liquid manure below the soil surface.	Prevention
Conservation Tillage	Any tillage and planting system that leaves a minimum of 30% of the soil surface covered with plant residue after the tillage or panting operation (for example, reduced till, no-till)	Prevention
Reduced Phosphorus Manure	A 20% reduction of the total Phosphorus content being applied to fields through either manure or fertilizer.	Avoidance
Grassed Waterways	Stabilizing areas that are sensitive to erosion by establishing grass-lined swales.	Prevention
Grassed Riparian Buffers	Areas of grasses or shrubs (which may include trees) located adjacent to ponds, lakes, and streams that filter our pollutants from runoff.	Prevention
Fencing Livestock Inclusion	Exclusion of livestock from waterways and stream banks by installing fence.	Prevention
Barnyard Runoff Management	Exclusion of clean water runoff from the barnyard and heavy-use area and management of the remaining runoff in a way that minimizes pollution.	Prevention
Crop to Hay	Permanent conversion of crop land use to hay.	Prevention
Field Ditch Buffer	Grassed strips along the drainage ditches that filter our pollutants from the adjacent land runoff.	Prevention

Note. BMPs as described by Tetra Tech (2015).

Noticeably, the focus is on phosphorus *prevention* BMPs, which is understandable. Prevention techniques allow farmers to maintain the conventional production model, continuing to use fertilizers while also importing feed to support animal development. As mentioned previously, conventional farming has come to rely extensively on phosphate inputs as fertilizer to increase yields for food security in the wake of urban population growth and the decline of rural communities (Cordell et al., 2009). A recent study showed that 15% of P applied as fertilizer to row crops makes it to the food consumer while 66% is lost to the environment (Suh & Yee, 2011). The ratio is even lower in animal agriculture (Schipanski & Bennett, 2012). By implementing *avoidance* measures, restricting the amount of P entering the system, there may be constraints on the production yields for agricultural crops where soils are deficient in P.

Avoidance methods to reduce P may include land conversion from crop to pasture or pasture to forest, nutrient management planning requiring P input reduction, fertilizer taxation, manure recycling, or multifunctional policy that limits the amount of agricultural inputs entering a system and manure within the system.

When avoidance and prevention techniques do not reduce or treat downstream pollution remediation strategies can be employed to remove P from waterways or treat the symptoms of pollution. These strategies include physical, chemical, and biological remediation (Office of Water, 2015). An example of a biological control is catalyzing grazing pressure from aquatic organisms that feed on cyanobacteria (i.e. trophic manipulation). In addition, dredging of P from sediments can help address legacy P. Conventional remediation techniques are oftentimes expensive and complex (e.g.

dredging), which ultimately limits their use in water systems (Gautam & Banerjee 2014; Loganathan et al. 2014).

Eutrophication, stimulated by P runoff from landscapes, compromises water quality and can have long-term impacts on recreation (Dodds, 2008), property values (Gibbs et al., 2002), aquatic food webs (Dodds, 2008) and drinkability (Liu et al., 2011) of bodies of water. In the State of Vermont, efforts are underway to control the amount of P entering Lake Champlain per standards set forth in the Federal Clean Water Act by preventing the nutrients from flowing off the farm parcel. The studies presented in this paper will introduce two independent methodologies proposed to aid in the farmer's willingness to implement *avoidance* and *prevention* pro-environmental practices, (1) determining farmer values towards implementation of best management practices to inform policy, and (2) creating a multifunctional sustainability prioritization scheme for dissemination of Clean Water Fund resources.

2.1. Research Justification

The two articles presented in this paper confront the financial resource limitations of Act 64 by constructing ways to get a greater return on the money invested in P runoff reduction. The alternative methods presented in this paper are intended to boost the farmer's willingness to participate in *avoidance* and *prevention* pro-environmental practices by understanding their needs and using them to designing policy, and to create a funding prioritization scheme that is based upon performance.

2.2. Determining Farmer Values for Implementing Pro-Environmental Practices

How actors make decisions has been studied in many academic disciplines including classic economics and consumer marketing (Chorus et al., 2013; Sheth et al., 1991) These two fields evaluate the way consumers make decisions using different methodologies. In Walrasian economics an actor is weighing the decision between purchasing x quantity of product A and x quantity of product B depending upon their income constraints (Mathis & Koscianski, 2002). This theory of consumption carries multiple assumptions that have been challenged by the economists (Gowdy, 2009). Additionally, research from the field of behavioral economics, evolutionary game theory, and neuroscience have concluded that decisions are made using social context and endogenous values, not solely on rationalization (Camerer et al., 2003; Ratchford, 1975). This being known, marketing consumption theory has actively examined the functional, emotional, social, epistemic, and conditional values that inform a consumer's decision to purchase a good or service (Sheth et al., 1991).

A choice is the result of a decision making process involving more than one alternative, each alternative has associated consequences and rewards, an evaluation precedes the final choice, and the evaluation uses outside information and memory to determine the ultimate selection (Olshavsky & Granbois, 1979). Using the validated theory of Sheth et al. (1991) we can conclude that the actor's endogenous values associated with determining the consequences of alternatives are functional, emotional, social, conditional, and epistemic and assist in the formation of a final choice.

Functional value is correlated with the perceived utility an actor acquires from the performance of a product or service. Applied to the question of soil fertility management plans on a vegetable farm, the functional option would deliver the greatest crop yield. The social value is linked to the amount of utility the actor would get by connecting with one or more social groups by selecting an alternative that best suits the expectations of a desired social group. For instance, the use of organic fertilizers as opposed to conventional types may allow for acceptance into a desired social group. The emotional value is the utility derived from feelings associated with choosing an alternative. In this situation, the farmer may feel emotionally attached to a certain nutrient management plan based upon past experiences with it or an alternative. The farmer could also feel emotionally attached to the water quality externalities that are a byproduct of using different nutrient management plans. Conditionality is the association between a decision and its context. For instance, if this farmer thought that under the condition that they applied more P to the land the eutrophication would become worse downstream, then they may have reservations about the decision to apply P to the field. The epistemic value associated with decision-making is the alternatives ability to arouse curiosity, stimulate novelty, or satisfy a desire for knowledge. The farmer may prioritize any one, or a combination of, these values in an effort to choose the best fertility plan for the vegetable farm.

The Vermont Water Quality Act proposes Required Agricultural Practices (RAP) for agriculture in the state with a limited understanding of what the farming community desires from such a policy. This paper's first article titled, "Determining Farmer Values for Implementing Pro-Environmental Practices," analyzes twenty-four farmers and their associated values towards adopting pro-environmental practices for improved water quality. A hierarchical cluster analysis was used to segment farmers according to their adoption of best management practices on their farms. Further, a one-way analysis of variance (ANOVA) was conducted using dependent functional (quality), functional (price), and emotional, social, conditional, and epistemic variables to understand the variance between the segments. The results from this analysis illuminate farmer values. This information can be used to inform water quality policy, ecosystem service payments, communication strategy, and funding dissemination.

2.3. Prioritization of Farm's For Subsidies: A Multifunctional Approach

Using multiple criteria to evaluate agricultural production has become significantly more common in analyzing our food system (Gómez-Sal et al., 2003; Renting et al., 2009). The multifunctional agricultural movement measures both the commodity and non-commodity outputs of agriculture to support rural development goals and food production incentives (Renting et al., 2009). This inclusive view spawned from neo-classical economics where negative externalities of production were deemed market failures. In this classical ideology the costs of economic growth fell upon the shoulders of the uninvolved parties while the benefits were attained by non-local parties. Measuring all externalities, both positive and negative, of agriculture allows for the internalization and liberalization of food production. This holistic approach has allowed geographic regions to leverage agriculture to provide regional food security, reduction in poverty, the creation of aesthetic landscapes, and cultural legacy (Millennium Ecosystem Assessment, 2002).

The Clean Water Fund was created to support the implementation of water quality initiatives in various sectors throughout the State of Vermont. The resources within the account are limited; therefore careful prioritization of farms for funding and outreach is essential. In the article titled, “Prioritizing Farms for Subsidies: A Multifunctional Approach,” a prioritization methodology is presented using theory from the sustainable multifunctional agriculture literature. In the analysis, Geographic Information Systems (GIS) software was used to map environmental practices on twelve farm landscapes to generate a spatial representation of environmental stewardship that was then translated into an environmental score. This environmental score was combined with social and economic data to prioritize farms based upon their multifunctional sustainability. This ranking methodology may be useful for the State of Vermont in determining the prioritization of Clean Water Fund resources using farm sustainability measurements. This is a novel method and is intended to meet long-term food system goals within the state. Practically, this method would work best in conjunction with a short-term solution that targets the critical source areas.

CHAPTER 3: DETERMINING FARMER VALUES FOR IMPLEMENTING PRO-ENVIRONMENTAL PRACTICES

The study of ecosystem services (ES) – the benefits derived from nature for human wellbeing – is gaining momentum as a conservation platform for communicating, guiding, and creating policies that prioritize conservation efforts using novel concepts. A novel ecosystem service policy, Payments for Ecosystem Services (PES), embeds the Environment into the economic landscape by valuing ecosystem services as items that can be voluntarily bought and sold in the market for ecosystem services. Traditionally, PES policy is created with little understanding of the ES suppliers' values towards adopting the policy practices. This study examines phosphorus runoff reduction as an ecosystem service and the agricultural sector as potential ecosystem suppliers. Using marketing theory we attempt to understand the values farmers' use to decide whether or not to adopt best management practices for phosphorus runoff reduction. Using marketing theory we determine what factors most influence the farmers' decision to adopt the best management practice. This information will allow us to inform policy, pricing, distribution, and communication in a way that is more appealing for farmers and may lead to increases in participation and the procurement of ecosystem services.

Phosphorus (P) is a chemical element found naturally in phosphate-based minerals and organic waste. This eleventh most common nutrient is a critical component of living organisms and consequently food production (Childers et al., 2011). Fertilizers containing phosphate-rock and manures are applied to fields to boost plant growth in some agricultural systems—a technique proposed in the green revolution to increase crop yields. If the land cover cannot assimilate the applied P then it may run off of the parcel into local waterways (Reddy et al., 1996). When high concentrations of P are present in water and environmental conditions are right, eutrophication may occur, catalyzing the growth of harmful cyanobacteria blooms (Bennett et al., 2001). Blooms can have a negative impact on local economy such as financial losses from reduced water recreation, waterfront property values, and quality of drinking water (Dodds et al., 2009).

The Clean Water Act (CWA) is a federal law in the United States that is responsible for ensuring water quality standards (US EPA, Summary). The

Environmental Protection Agency (EPA) enforces the CWA by monitoring the health of the nation's water by requiring each state to submit a Water Quality Assessment Report every two years under section 305(b) and 303(d) of the CWA. In 2008, Vermont submitted data to the EPA on the health of their 229,722 acres of lakes and reservoirs. Of the lakes and reservoirs surveyed, 61% were deemed impaired due to nutrient-related causes (US EPA, 2011). Lake Champlain, the sixth largest waterbody in United States with boundaries in the states of Vermont and New York, USA and Quebec, Canada experiences cyanobacteria blooms in the late summer. The lack of ecological balance in this waterbody has led to its classification as an impaired waterbody due to nutrient-related causes.

When a waterbody is classified as impaired, the EPA will set a level for the Total Maximum Daily Load (TMDL) of that pollutant into the lake. In 2002, the EPA set an initial TMDL for P entering Lake Champlain from the State of Vermont and New York. Due to non-compliance, the TMDL in Vermont was legally challenged and revoked by the EPA in 2011 (US EPA, 2011). Since this time the EPA has issued a new TMDL with stricter standards requiring a large reduction in P loads for each of the Vermont watersheds bounding Lake Champlain. For example, Missisquoi Bay and its source sub-watershed are now required to reduce the TMDL of P by 64.3% which means a reduction of 82.6% from the agricultural sector (US EPA, 2015).

Regulation of standards set forth in the CWA controlled through a permitting process called the National Pollutant Discharge Elimination System (NPDES) which targets point sources of pollution. Point sources of pollution have been defined in the

Clean Water Act in section 502(14) as "...any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture." From a management perspective, control of pollutants coming from a pipe is simpler than regulating the non-point sources of pollution.

In addition to point sources of pollution there are non-point sources (NPS) of contamination. This source is described by the Clean Water Act as any source of pollution that does not meet the criteria set forth in the definition of point-source of contamination. General sources include: land runoff, precipitation, and drainage. This type of mobilization transports nutrients into lakes, rivers, wetlands, coastal waters and ground waters. These non-point sources are complex and difficult to regulate due to their flow through the environment instead of through a pipe like the point source pollutants.

Act 64 has created a set of required agricultural practices (RAP) that address non-point sources of P runoff from agricultural land based on the size of the farm. According to the State there are three designations of farms: the small farm operation (SFO), medium farm operation (MFO), and the large farm operation (LFO). Each type of farm operation will need to complete a certification declaring implementation of set RAP starting on July 1st, 2017. An additional permit is required for Concentrated Animal Feeding Operations (CAFO) that are either MFO or LFO in size. Proposed RAP's include a field-to-field 590 Nutrient Management Plan, vegetative buffer zone, animal mortality management, cover cropping, reduced tillage, exclusion of livestock, and an inspection within five years (Vermont Agency of Agriculture, Food and Markets, 2015). The SFO's must complete a required education course for farmers and annually submit a report of compliance to the State of Vermont.

Complexity arises with the amount of funds available in regards to the amount of change that needs to be implemented across a considerable number of farms in the State. The State of Vermont has created a Clean Water Fund that is designated for the funding and outreach to help farmers implement the appropriate suite of practices on their farm. Money will be generated for this account via a 0.2 percent property transfer tax surcharge, farm permit fees, and penalties paid by non-complying farmers. The CWF will generate approximately $5.3 million dollars annually for meeting water quality standards. As mentioned previously, this act will support farmers in implementing RAP but will also be used to hire at least eight and at most twenty-one positions that will work directly on monitoring and evaluating the Vermont Clean Water initiative and the Lake Champlain TMDL.

These funds are small for the amount of action necessary to clean up P runoff in the State of Vermont. Thus, it is important for the State of Vermont to get the greatest return on their money invested in the effort to control P runoff from agricultural land. The payments for ecosystem services (PES) model provides a framework in which to evaluate the values farmers use when deciding upon whether or not to implement an environmental practice on their farm.

Reducing heterogeneous populations down to smaller more homogenous groups is the act of segmentation (Venugopal & Baets, 1994). This methodological process has been used effectively, with informative results, in demand-oriented willingness to pay (WTP) studies (Morey et al., 2008). Within the literature, there has yet to be discovered an attempt to segment potential ES sellers based on their adoption of conservation (BMP) practices. This study will fill the literature gap by developing landowner segments based on their adoption of best management practices and using a one way ANOVA test to analyze the difference between segments and their endogenous values.

Conceptual Framework

This study uses the PES framework to treat water quality as a benefit obtained by Vermont residents from upstream landowners restricting nutrients from running of their land. In this sense, the provisioning of clean water has been embedded in the market model allowing for examination using market instruments including consumer decision making. In this study we will cluster farmers into four segments representing environmental stewardship based on implementation of best management practices. Then we will evaluate the variance between the groups according to their endogenous associations with pro-environmental agricultural policy to increase water quality in their region. The results will illuminate differences between the groups to inform policy, payments, distribution, and communication to reflect the wants of the agricultural community.

Payments for Ecosystem Services

The degradation of ecosystems and the services they offer is moving at a greater pace than the science, policy, and social mechanisms used to mitigate the degradation (Mooney et al., 2010). In an effort to understand the situation more clearly, the Millennium Ecosystem Assessment (MA) analyzed the ecosystem changes in the last fifty years and the impacts the changes had on human well-being (Millennium Ecosystem Assessment, 2005). Scientists used this assessment to aid institutions in making informed decisions regarding the environment.

The report grouped benefits according to how they contribute to the sustainment of life; provisioning, regulating, cultural, and supporting. Humanity uses water in many ways including consumption, growing food, recreation, and tourism. The report states that fresh water plays a critical role in humanity and that there are challenges to maintaining its quality. The major pollutants deteriorating our water quality are nutrients that cause eutrophication (Millennium Ecosystem Assessment, 2005).

This assessment yields the status of our ecosystems and a way for us to measure how the changes have had an impact on humanity. Thus, the evolution of the term 'Ecosystem Services,' the human benefits obtained by nature. These benefits are numerous and oftentimes difficult to understand, quantify, and communicate due to their intangible nature. The Millennium Ecosystem Assessment presented a scheme for quantifying the total economic value of the service provided. The value, although not intended to be economic, can be monetized and used to generate the PES policy (Sánchez-Azofeifa et al., 2007; Turpie et al., 2008). The market for PES can be understood as a voluntary transaction between at least one service user and at least one service seller for a defined ecosystem service that is conditional on the service being delivered by the seller (Wunder, 2005). This framework is focused on the environmental benefits sought and the amount they are worth but not the people who are either giving or receiving the service. PES tends to factor economic and ecological values without any consideration of social implications.

Before a PES policy is implemented much work has to be done to identify the ecosystem of interest and its bio-physical function (Luck et al., 2009). Once the ecology is known we can begin to define the services delivered from the ecosystem, how humans benefit from it, and how much they benefit. Then, it is up to the policy makers to design systems that work best for those receiving and offering the ecosystem service. If the values of the ecosystem providers are known and the PES policy matches their needs, then there may be an increase in participation.

Marketing Theory

Currently, the PES policies are understandably hyper-focused on the ecological and economic component. The marketization of ecosystem services through PES allows for the ideology to become analyzed using business theory. Employing marketing as a third focal point may create new social information for decision-makers outside ecology and economics. This new information may help inform PES to deliver value beyond monetary compensation. To date, marketing in the context of PES has primarily evaluated the demand- side of the PES policy, trying to understand the needs of landowners and their Willingness to Pay (WTP) for ecosystem services (Moreno-Sanchez et al., 2012). In the past seven years a few studies have emerged trying to understand the supply-side's willingness to adopt (WTA) conservation practices (Bremer & Lopez-Carr, 2014; Kosoy & Brown, 2008; Yu & Belcher, 2011). Bremer's study evaluated a PES policy in Ecuador with goals of poverty alleviation and community development to find that larger more wealthy landowners were able to participate in the program over smaller less wealthy landowners. This was due to the high upfront costs associated with program participation. By looking at the current literature, there seems to be a gap in understanding the endogenous values that ecosystem service provider's use when deciding to implement a best management practice.

How actors make decisions has been studied in many academic disciplines including classic economics and consumer marketing (Chorus et al., 2013; Sheth et al., 1991). These two fields evaluate the way consumers make decisions using different methodologies. In Walrasian economics an actor is weighing the decision between purchasing x quantity of product A and y quantity of product B depending upon their income constraints (Mathis & Koscianski, 2002). This theory of consumption carries multiple assumptions that have been challenged by the ecological economic field (Gowdy, 2009). Additionally, research from the field of behavioral economics, evolutionary game theory, and neuroscience have concluded that decisions are made using social context and endogenous values, not solely on rationalization (Camerer et al., 2003; Ratchford, 1975). This being known, marketing consumption theory has actively examined the functional, emotional, social, epistemic, and conditional values that inform a consumers decision to purchase a good or service (Sheth et al., 1991).

A choice is the result of a decision making process involving more than one alternative, each alternative has associated consequences and rewards, an evaluation precedes the final choice, and the evaluation uses outside information and memory to determine the ultimate selection (Olshavsky & Granbois, 1979). Using the validated theory of Sheth et al., 1991 we can conclude that the actor's endogenous values associated with determining the consequences of alternatives are functional, emotional, social, conditional, and epistemic and assist in the formation of a final choice. To understand the way different groups of farmers evaluate the consequences of alternatives in the decision making process involves segmenting groups based upon their observed traits. In this case, we will be segmenting farmers based upon their adoption of best management practices.

Reducing heterogeneous populations down to smaller more homogenous groups is the act of segmentation (Venugopal & Baets, 1994). This methodological process has been used effectively, with informative results, in demand-oriented WTP studies (Morey et al., 2008). Morey found that he could segment ecosystem service users' into four classes: preservation, strong non-use preservation, moderate use-value preservation, and if at all. These segments were used to predict bids to pay for ecosystem services. Within the literature, there has yet to be discovered an attempt to segment potential ES sellers based on their adoption of a conservation (BMP) practice. This study will fill the literature gap by developing landowner segments based on their adoption of best management practices and using a one way ANOVA test to analyze the difference between the segments and their endogenous values.

We will assume that in the same way these values are used by the consumer to decide upon a product, a farmer will use these values to deduce the trade-offs of implementing a best management practice on the farm. Thus, we move beyond the traditional theory that all decisions are made to maximize the utility of the individual under the constraints of income and price.

Table 2: Endogenous Values Measured

Value	Definition
Functional	The perceived utility acquired from an alternative's capacity for functional, utilitarian, or physical performance.
Social	The perceived utility acquired from an alternative's association with one or more specific social group.
Emotional	The perceived utility acquired from an alternative's capacity to arouse feelings or affective states.
Epistemic	The perceived utility acquired from an alternative's capacity to arouse curiosity, provide novelty, and/or satisfy a desire for knowledge.
Conditional	The perceived utility acquired by an alternative as the result of the specific situation or set of circumstances facing the choice maker.

Note. Endogenous values of Sheth et al., (1991).

A graphical representation of the harmonization of PES theory and marketing theory is presented in Figure 2. In the figure there exists two possible scenarios for a potential farmer. They could convert their forested land to pasture having economic benefits for themselves and costs to those living downstream that need vegetation to control erosion and filter nutrients. This would be at a cost to those living downstream. An alternative would be keeping his land in forest which has less of a benefit unless he/she gets paid to do so at least a little more than if he converted to pasture. The logic of ecosystem services proposed by (Pagiola & Platais, 2008) and illustrated by (Engel et al., 2008) was adapted to include the functional, emotional, social, epistemic, and conditional values (Sheth et al., 1991) and the PES marketing mix.

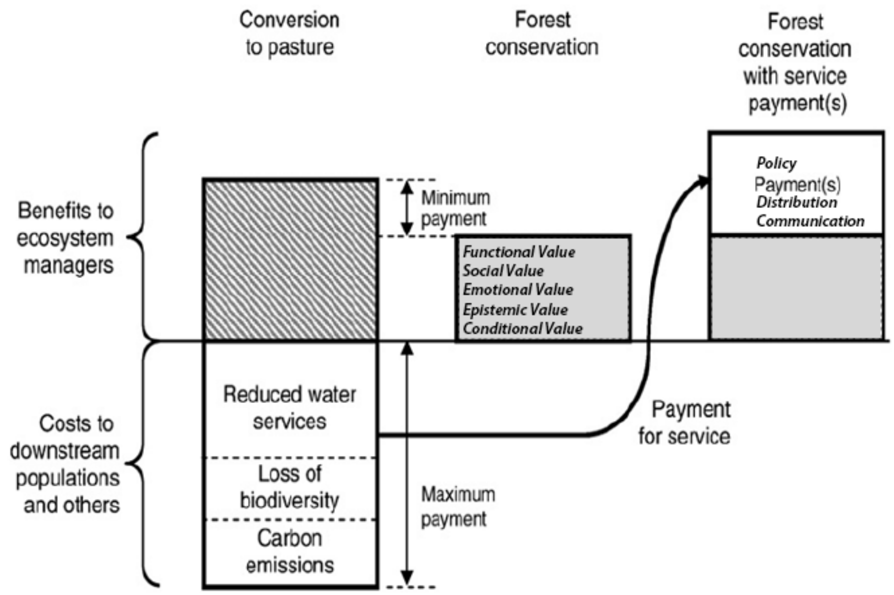

Figure 2: Accounting for Endogenous Values in the Framework of Ecosystem Services. Logic of ecosystem services proposed by Pagiola & Platais (2008), illustrated by Engel et al., (2008) and adapted by Brown (2016) to include endogenous values and the PES marketing mix.

We are interested in understanding whether farmers use a set of endogenous values to evaluate whether or not to adopt an agricultural BMP without financial incentives. Classically, within the PES framework, we have viewed adoption decision-making to be a tradeoff between the opportunity cost of implementation and the financial incentive. This study analyzes adoption without financial incentives to understand whether the farmer evaluates more than just financial gains and losses in making the decision to adopt an agricultural BMP for P runoff reduction. Our null hypothesis is as follows:

H_{01}: There is no significant variance between functional value (quality) and adoption of Best Management Practices.

H_{02}: There is no significant variance between functional value (price) and adoption of Best Management Practices.

H_{03}: There is no significant variance between emotional value and adoption of Best Management Practices.

H_{04}: There is no significant variance between social value and adoption of Best Management Practices.

H_{05}: There is no significant variance between epistemic value and adoption of Best Management Practices.

H_{06}: There is no significant variance between conditional value and adoption of Best Management Practices.

If we reject any of the above null hypotheses then we can conclude that farmers make the decision to adopt best management practices not only evaluating opportunity costs and financial incentive but based on the impacts of the process as a whole. This may be significant in understanding how to build policy, pricing, distribution, and communication to meet the needs of these farmers.

Data[1]

Small multifunctional farms were selected as the target population for this study. In addition to food and fiber, these farms produce non-commodity outputs that have can have positive or negative impact on society (UNCED, 1992). Examples of multifunctional activities (MFA) are: building social capital through direct sales, stewarding the environment by using agricultural best management practices, and/or creating local economy by selling food and fiber within the region. For this study, we will

[1] See Appendix A for the sample profile.

be looking at the actor-oriented approaches to multifunctional agriculture by examining the ‘broadening,’ ‘deepening’ and ‘re-grounding’ of agriculture in society (Van der Ploeg et al., 2003). This multifunctional classification scheme categorizes the manner in which a farm departs from conventional agriculture models on their farm (Renting et al., 2009). Broadening economic activity is a farm’s creation of alternative products and services. These can be accounted for by measuring agri-tourism and value addition. Deepening occurs when a farm produces a good or service that meets the needs of the consumer and can be measured by examining direct sales. Re-grounding is understood as a refocusing of household activities, this can be investigated by evaluating the amount a farm family works off the farm. The alternative market channels investigated to determine the degree of multifunctionality are agri-tourism, value addition, direct sales, and off-farm income. We used this classification scheme to select farmers based upon their multi-functionality. This segment was used to test the methods within this paper. For this reason, the sample is inherently environmentally conscious and data may be skewed. In future research, the sample will include conventional farms selling only to wholesale markets. The addition of these farmers may yield more statistically significant data.

The sample was accumulated from an array of food networks in Chittenden County although farmers represent several parts of the State of Vermont. The first collection of contacts was at the Vermont Vegetable and Berry Association annual meeting in the spring of 2015. The second collection of contacts was from the Rutland Food Area Guide (RFAG). The RFAG lists the small and medium sized farms in Rutland county, their contact information, what they produce, and whether or not they’re open to visitors. Contacts from these two groups were approached to become part of the study by an initial phone call with a follow-up mailing of the survey instrument. From the first round of recruitment we mailed questionnaires to sixty farmers with thirteen of them returning a completed survey. We then offered an $80 compensation for filling out the survey and participating in an hour-long farm visit by a research assistant. With this compensation we gained five participants from the original sample. From there we decided to contact farmers engaged at the Burlington and Winooski Farmers' Markets, adding an additional six participants to the sample. In total, there are twenty-four farms that were included in this study.

The major limitation of this study is the sample size and the representation of the sample. The sample size is not large enough to reflect the values of the farming population in Vermont. In addition, the sample does not accurately account for all types of production and business typologies within the state. The dairy industry is not represented in the sample but dominates agricultural land use in the State of Vermont. Land designated for the dairy industry covers 900,000 acres or 80% of the total farm acreage in the State of Vermont (USDA Census of Agriculture, 2012). This study used a sample of small multifunctional farms to test methodologies before scaling the study to larger conventional farms within the State. The reason why this was done was to reform both the survey instrument and the methods before conducting a study at a larger scale.

Best Management Practices

Common agricultural practices were used in this study as a proxy for general environmental stewardship on a farm. We used a suite of Best Management Practices (BMPs) taken from the Lake Champlain BMP Scenario tool (Tetra Tech, 2015). The list of BMPs and associated descriptions are given in Table 3.

Table 3: Best Management Practices

Best Management Practice	Abbreviation	Description
Cover Cropping	CC	Establishing a seasonal cover on annual cropland for soil erosion reduction and conservation purposes. Cover cropping would consist of a crop of winter rye or other herbaceous plants.
Changes in Crop Rotation	CR	Standard rotations. For example, rotations of corn to hay and rotations of corn to soybean.
Alternative Manure Incorporation	AMI	Applying liquid manure below the soil surface.
Conservation Tillage	CT	Any tillage and planting system that leaves a minimum of 30% of the soil surface covered with plant residue after the tillage or panting operation (for example, reduced till, no-till)
Reduced Phosphorus Manure	RPM	A 20% reduction of the total Phosphorus content being applied to fields through either manure or fertilizer.
Grassed Waterways	GW	Stabilizing areas that are sensitive to erosion by establishing grass-lined swales.
Grassed Riparian Buffers	RP	Areas of grasses or shrubs (which may include trees) located adjacent to ponds, lakes, and streams that filter our pollutants from runoff.
Fencing Livestock Inclusion	FLE	Exclusion of livestock from waterways and stream banks by installing fence.
Barnyard Runoff Management	BRM	Exclusion of clean water runoff from the barnyard and heavy-use area and management of the remaining runoff in a way that minimizes pollution.
Crop to Hay	CH	Permanent conversion of crop land use to hay.
Field Ditch Buffer	FDB	Grassed strips along the drainage ditches that filter our pollutants from the adjacent land runoff.

Note. BMPs as described by Tetra Tech (2015).

The data regarding adoption of BMPs was collected via a mail survey. Respondents were asked to declare whether they were ‘Not Willing to Adopt,’ ‘Willing to Adopt,' 'Already Adopted BMP' or if the BMP is 'Not Application on [the] Farm' for each of the listed BMPs in Table 4.

In coding the responses, we collapsed four categories down to two, 'Already Adopted BMP' and 'Has Not Adopted BMP'. The second category was formed from condensing the 'Not Willing to Adopt' and "Willing to Adopt' as both of these responses signify that the farmer has not actually adopted the BMP at the time of the survey.

If a particular BMP was 'Not Applicable on the Farm' or 'Already Adopted BMP' then we coded as 'Already Adopted BMP.' If the principal operator decided upon a production that did not require the implementation of a BMP then they were rewarded for doing so by declaring the practice as already adopted. For example, if cover cropping on a maple farm is not applicable then they should not be coded as 'Has not Adopted BMP,' as 'Already Adopted BMP' will be more beneficial to the farmer. In future studies, the 'Not Applicable on the Farm' will not be coded at all. The principal operators filling out the survey were asked to assume that there would be no financial incentives for implementation and management of the BMPs.

Endogenous Values

The dependent endogenous variables measured to test the declared null hypotheses were measured in the mail survey using the following constructs: Q1, Q2, Q6, Q9, Q15, and Q23. These variables were selected due to their representation of the endogenous value being considered. Each one of the constructs is associated with an endogenous value presented in the literature review (see Table 4 for their description). The respondents were asked to select whether or not they agree, are neutral, or disagree with the statement. The responses were coded into ordinal data as follows: agree = 1, neutral = 0.5, and disagree = 0.

Table 4: Constructs Measuring Endogenous Values

Question Number	Endogenous Value	Construct
Q1	Functional (Quality)	Using pro-environmental practices will/does improve the overall quality of my food/product (appearance, taste, texture, smell, nutrients)
Q2	Functional (Price)	Making good environmental decisions on my farm increases my income
Q9	Emotional	Farming using pro-environmental practices does feel like making a personal contribution to something better
Q23	Social	Using pro-environmental practices on my farm helps the way I'm perceived in the community
Q6	Epistemic	I farm to connect with the community
Q15	Conditional	We can gain more watershed benefits if we can restrict pollution from farm production

Note. Constructs developed from the endogenous values of Sheth et al., (1991).

Empirical Methods

The first step in the data analysis was to cluster farmers according to their adoption of BMPs on their farm. This is used as a proxy of environmental stewardship. Then, after the clusters were formed a one-way analysis of variance (ANOVA) was conducted to realize the significant differences between the groups in regards to their endogenous values.

To perform the cluster analysis, the BMP data was condensed into binary data. For any of the BMPs listed the subject was able to answer from four categories of responses that they felt best suited their farm. The options to select from were 'Not

Willing to Adopt,' 'Willing to Adopt,' 'Already Adopted BMP,' and 'Not Applicable on My Farm.' The researcher coded the responses into a binary scale based upon whether or not the BMP had or had not been implemented on the farm. The 'Not Willing to Adopt' and 'Willing to Adopt' was assigned a value of '0' because they had not adopted the BMP. The 'Already Adopted BMP' and 'Not Applicable on My Farm' were coded as '1' because they had already adopted the practice or their production did not require adoption.

From the binary data, a percentage was created of adoption for each farm by averaging the BMPs coded with a '1' and '0', see Table 3. We multiplied this number by 100 to produce a continuous variable to be used in the cluster analysis. The variable was named, 'Adoption of BMP.' The continuous values for this variable ranged between 50 and 100 for each one of the twenty-four farms.

Table 5: Condensation of the Adoption of Best Management Practices

Production	Farm ID	CC	CR	AMI	CT	RPM	GW	RB	FLE	BRM	CH	FDB	AVG	Adoption of BMP
Meat	1	0	1	1	0	0	0	1	1	1	1	1	0.64	63.64
Meat	2	1	1	1	0	1	1	1	1	0	1	1	0.82	81.82
Meat	3	1	1	1	-	0	0	1	1	1	1	1	0.80	80.00
Meat	4	1	1	1	1	1	1	1	1	1	1	0	0.91	90.91
Maple	5	1	1	0	1	1	1	1	0	1	1	1	0.82	81.82
Maple	6	1	0	1	1	1	1	1	1	1	0	1	0.82	81.82
Maple	7	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Maple	8	1	1	1	1	1	0	1	1	1	1	0	0.82	81.82
Veg. & Meat	9	1	1	1	0	1	1	1	1	1	1	1	0.91	90.91
Veg. & Meat	10	1	1	1	0	1	1	1	1	1	1	1	0.91	90.91
Veg. & Meat	11	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Veg. & Meat	12	0	1	1	0	1	1	1	1	1	1	1	0.82	81.82
Veg. & Meat	13	0	1	0	0	0	0	1	1	1	-	1	0.50	50.00
Veg. & Meat	14	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Vegetable	15	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Vegetable	16	1	1		0	0	1	1	1	1	1	1	0.80	80.00

Vegetable	17	1	1	1	1	1	1	1	0	1	1	1	0.91	90.91
Vegetable	18	1	1	1	1	1	1	0	1	1	1	1	0.91	90.91
Vegetable	19	1		1	1	1	1	1	1	-	1	1	1.00	100.00
Vegetable	20	0	1	1	0	1	1	1	1	1	1	1	0.82	81.82
Vegetable	21	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Vegetable	22	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Vegetable	23	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00
Vegetable	24	1	1	1	1	1	1	1	1	1	1	1	1.00	100.00

Using JMP Pro we performed a multivariate cluster analysis. The Y variable used to run the cluster analysis was ‘Adoption of BMP.’ We used a hierarchical cluster method due to the small sample size and Ward minimum variance to determine the distance between segments. The Ward method was chosen to determine distance as it is biased towards creating clusters with a smaller amount of observations. The hierarchical cluster analysis generated four segments of farmers based on their similar adoption patterns, see Table 6. Cluster #1 was categorized as having a ‘High Potential to Adopt BMP,’ cluster #2 a ‘Moderate Potential to Adopt BMP,’ cluster #3 a ‘Low Potential to Adopt BMP,’and cluster #4 ‘Potential Achieved.’

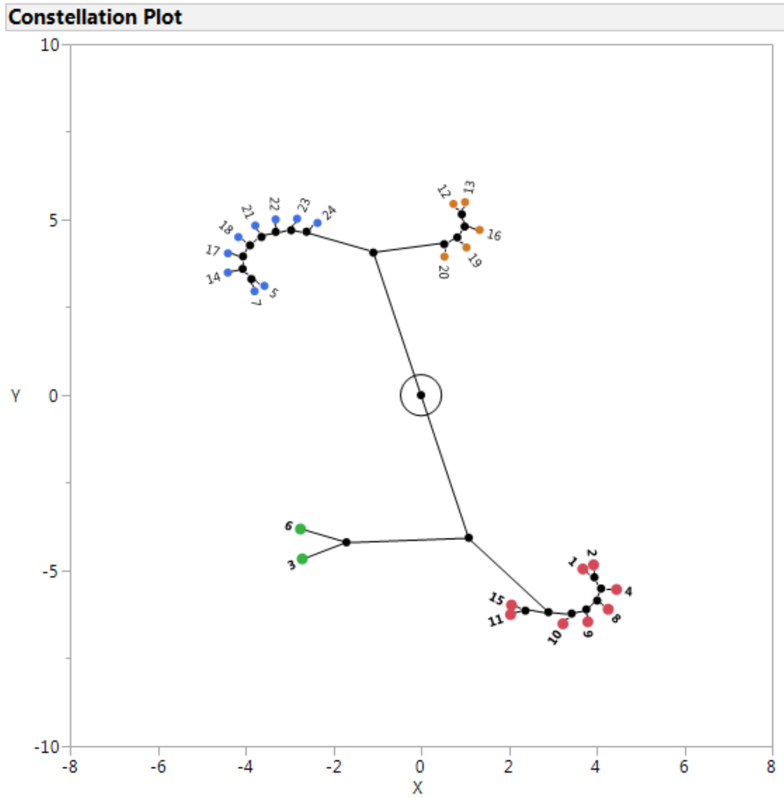

Figure 3: A Constellation Plot Representing the Group Separation among the Sample

Table 6: Mean Adoption of Best Management Practices for each Cluster

Cluster	Category	Count	Cluster Mean
1	High Potential to Adopt	2	56.818
2	Moderate Potential to Adopt	5	90.909
3	Low Potential to Adopt	8	96.753281.364
4	Potential Achieved	9	100

After identifying the segments, a one-way ANOVA of variance is conducted using the four groups identified in Table 6. This test is used to determine whether the means (μ) of the independent segments (μ_1, $\mu_{2,}$ $\mu_{3,}$ $\mu_{4)}$ are equal for each endogenous value being tested. If the distance between means is statistically significant, then we can reject the null hypothesis associated with the dependent endogenous variable and declare that there is a variance between farmer adoption of BMPs and associated endogenous values as determined by one-way ANOVA.

Therefore, we will re-state the null hypotheses being tested as follows:

H_{01} : μ_1 (Q1) = μ_2 (Q1) = μ_3 (Q1) = μ_4 (Q1)
H_{02} : μ_1 (Q2) = μ_2 (Q2) = μ_3 (Q2) = μ_4 (Q2)
H_{03} : μ_1 (Q9) = μ_2 (Q9) = μ_3 (Q9) = μ_4 (Q9)
H_{04} : μ_1 (Q23) = μ_2 (Q23) = μ_3 (Q23) = μ_4 (Q23)
H_{05}: μ_1 (Q6) = μ_2 (Q6) = μ_3 (Q6) = μ_4 (Q6)
H_{06} : μ_1 (Q15) = μ_2 (Q15) = μ_3 (Q15) = μ_4 (Q15)

The data was uploaded into SPSS Statistics Package #23 for the one-way ANOVA comparison of means. Once again the dependent ordinal variables being analyzed are Q1, Q2, Q6, Q9, Q15, and Q23. The factor being analyzed as the independent variable is the categorical cluster data comprising the four segments of farmers based on their adoption of agricultural BMPs.

Table 7: Results of the One-way ANOVA

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Q1	Between Groups	.333	3	.111	4.444	.015
	Within Groups	.500	20	.025		
	Total	.833	23			
Q2	Between Groups	.211	3	.070	.837	.490
	Within Groups	1.594	19	.084		
	Total	1.804	22			
Q6	Between Groups	.571	3	.190	1.983	.149
	Within Groups	1.919	20	.096		
	Total	2.490	23			
Q9	Between Groups	.083	3	.028	1.481	.250
	Within Groups	.375	20	.019		
	Total	.458	23			
Q15	Between Groups	.326	3	.109	2.065	.139
	Within Groups	1.000	19	.053		
	Total	1.326	22			
Q23	Between Groups	.215	3	.072	.942	.439
	Within Groups	1.524	20	.076		
	Total	1.740	23			

Results

From the one way ANOVA we can determine that there was a significant difference between the four segments in Q1 as determined by one-way ANOVA ($F(3,20)) = 4.444$, $p = 0.015$. Again, Q1 measured the functional quality of using pro-environmental practices on the farm. Therefore, we can reject H_{01} to conclude that there is a difference between cluster two and the rest of the clusters in regards to their belief that using pro-environmental practices will/does improve the overall quality of [their] food/product (appearance, taste, texture, smell, nutrients).

The second cluster or the segment with the 'lowest potential to adopt' had a mean answer to Q1 of 0.75 whereas the other three groups had answered 1 (agree) to the use of pro-environmental products improving the food//product quality. The one-way ANOVA fails to reject hypotheses H_{02} through H_{06}.

In future research the sample size should be expanded to accurately capture the farming population targeted for the reduction of P runoff. In addition to expanding the number of samples the type of production needs to be expanded to include the dairy sector and conventional farms. Once differences between conventional and alternative or animal and vegetable are accounted for we may see more variation in the data and thus more informative results.

Conclusions

The State of Vermont is interested in developing a policy that will deliver the most P runoff reduction amongst farmers. Residents of the state are paying taxes that support implementation of the BMPs to control runoff and farmers, the ecosystem service providers, are delivering a service to residents downstream. The ecosystem service is being bought and sold allowing researchers to prescribe common business analysis tools to make the market more efficient. Applying marketing concepts may yield information that will inform policy, pricing, distribution, and communication allowing for a greater procurement of ecosystem services.

In this study, the endogenous values of farmers were studied to determine whether there was a correlation between adoption of best management practices and endogenous values associated with pro-environmental behaviors. One of the null hypotheses we tested was rejected to conclude that there was a difference between adoption of BMPs and the belief that the use of pro-environmental practices improves the quality of the food/product. Three of the segments agreed with the statement. One of the segments, 'Lowest Potential to Adopt BMP,' showed variation in the response. This was surprising as this group had a large mean BMP adoption rate. This indicates that, farmers believe that there may be a tradeoff between using pro-environmental practices and quality of food/product for some farms. For example, if a sweet potato farm decides to use organic practices then they must switch their pesticide inputs to a more environmentally friendly product. This brand may not work as well as the non-organic type leaving the potatoes open to damage from disease and insect pests.

This type of information may help decision-makers understand the endogenous differences between those that are most likely to adopt BMPs and those that are less likely. For example, the group looking to achieve their potential for implementing BMPs is finding a compromise in food/product quality by switching to the use of pro-environmental practices. This could be confronted in policy by developing programs that help farmers retain food/product quality in their transition to implementing BMPs. This program could be supported by financial incentives, targeted towards those in cluster two with a low potential to adopt, and sophistically communicated in a way that highlights the true tradeoff.

This methodology may be refined to pull information from agriculturists. Understanding the values of farmer's in their adoption of BMPs for reduction of P runoff from their farms may aid in the overall success of Act 64. Results from a larger study using this methodology, grounded in the framework of ecosystem services and marketing theory, can be used to inform water quality policy, ecosystem service payments, communication strategy, and funding dissemination. An area of further research involves evaluating the impact of this type of policy creation, on the farmer's adoption of pro-environmental practices.

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CHAPTER 4: PRIORITIZING FARMS FOR SUBSIDIES: A MULTIFUNCTIONAL APPROACH

The Clean Water Fund was created to support the implementation of water quality initiatives in various sectors throughout the State of Vermont. The resources within the account are limited; therefore careful prioritization of farms for outreach is essential. In this study a prioritization methodology is presented using theory from the sustainable multifunctional agriculture literature. In the analysis, Geographic Information Systems (GIS) software was used to map environmental practices on twelve farm landscapes to generate a spatial representation of environmental stewardship that was then translated into an environmental score. This environmental score was combined with social and economic data to prioritize farms based upon their multifunctional sustainability. This ranking methodology may be useful for the State of Vermont in determining the prioritization of Clean Water Fund resources using farm sustainability measurements.

Phosphorus (P) is a chemical element found naturally in phosphate-based rock minerals and organic waste. This 11th most common nutrient is a critical component of life and consequently food production (Childers et al., 2011). Fertilizers containing phosphate-rock and manures high in nutrients, are applied to fields to boost plant growth in some agricultural practices—a technique proposed in the green revolution to increase crop yields. If the land cover cannot assimilate the applied P then it may run off of the parcel into local waterways (Reddy et al., 1996). When high concentrations of P are present in water and environmental conditions are right, eutrophication may occur, catalyzing the growth of harmful cyanobacteria blooms (Bennett et al. 2001). Blooms can have a negative impact on local economy such as financial losses from reduced water recreation, waterfront property values, and quality of drinking water (Dodds et al., 2009).

The Clean Water Act (CWA) is a federal law in the United States that is responsible for ensuring water quality standards (US EPA, n.d.). The Environmental Protection Agency (EPA) enforces the CWA by monitoring the health of the nation's water by requiring each state to submit a Water Quality Assessment Report every two years under section 305(b) and 303(d) of the CWA (US EPA, n.d.). In 2008, Vermont submitted data to the EPA on the health of their 229,722 acres of lakes and reservoirs. Of the lakes and reservoirs surveyed, 61% were deemed impaired due to nutrient-related causes (US EPA, 2011). Lake Champlain, the sixth largest waterbody in United States with boundaries in the states of Vermont and New York, USA and Quebec, Canada, experiences cyanobacteria blooms in the late summer. The lack of ecological balance and excess amounts of P has led to its classification as an impaired waterbody due to nutrient-related causes.

When a waterbody is classified as impaired, the EPA will set a ceiling for the Total Maximum Daily Load (TMDL) of that pollutant into the lake. In 2002, the EPA set an initial TMDL for P entering Lake Champlain from the State of Vermont and New York. Due to non-compliance, the TMDL in Vermont was legally challenged and revoked by the EPA in 2011 (US EPA, 2011). Since this time the EPA has issued a new TMDL with higher standards requiring a large reduction in P loads for each of the Vermont watersheds bounding Lake Champlain. Vermont must comply with an acceptable plan to reduce the P load into the lake.

The State of Vermont has recently enacted Act No. 64 (H.35) to improve the quality of the State's waters. This act is commonly referred to as the Vermont Clean Water Initiative. The State of Vermont considers the agricultural sector to be the greatest contributor of eutrophication in the Lake Champlain Basin. Therefore, they have prescribed rules and regulations outlined in Act No. 64 (H.35) for the agricultural sector. This document specifically addresses agricultural P runoff reduction and provides a complementary mix of required agricultural practices and monitoring and evaluation strategies. At this time, the rules are being evaluated and have yet to be enacted.

The funding used to support Act 64 is channeled through the Clean Water Fund (CWF). Funds will be generated for this account via a 0.2 percent transfer property tax surcharge, farm permit fees, and penalties to non-complying farmers. The CWF will generate approximately $5.3 million dollars annually for meeting water quality standards. As mentioned previously, this act will support farmers in implementing RAP but will also be used to hire at least eight and at most twenty-one positions that will work directly on monitoring and evaluating the Vermont Clean Water initiative and the Lake Champlain TMDL.

Funding for this caliber of a project is limited. Thus the State of Vermont will advise farmers to seek financial support for project implementation from outside sources. The farms that are considered to be a critical source of the P will be prioritized for funding for the CWF. This paper outlines a multifunctional approach to prioritization of farms for funding and outreach. The goal of this methodology is to get a greater return on the money invested in the programming and open up funding opportunities for farmers from other departments within the State of Vermont.

In this study we use a framework provided by the multifunctional agriculture literature. Through this framework we developed environmental, social, and economic proxies for agricultural sustainability that we used to prioritize the farms for funding and outreach. Data was collected from a sample of twelve farms in the State of Vermont using a mail survey, farm visits, and personal interview.

Conceptual Framework

Using multiple criteria to evaluate agricultural production has become significantly more common in analyzing our food system (Gómez-Sal et al., 2003; Renting et al., 2009). The multifunctional agricultural discipline measures both the commodity and non-commodity outputs of agriculture to support rural development goals and food production incentives (Renting et al., 2009). This inclusive view spawned from neo-classical economics where negative externalities of production were deemed market failures. In this classical ideology the costs of economic growth fell upon the shoulders of the uninvolved parties while the benefits were sought in distant places. In this paper, the uninvolved parties are the people living downstream of the agricultural production. The benefits are sought by those purchasing the food in distant places. Measuring all externalities, both positive and negative, of agriculture allows for the internalization and liberalization of food production. This multifunctional sustainability approach has allowed geographic regions to leverage agriculture in working towards regional food security, reduction in poverty, the creation of aesthetic landscapes, and cultural legacy (Millennium Ecosystem Assessment, 2002).

It is theorized that there are close to three hundred definitions of sustainability and sustainable development being used by multiple academic disciplines (Santillo, 2007). The first effort to define an intention to plan using sustainability principals occurred at the World Commission on Environment and Development in 1987 (Sneddon et al., 2006). In the publication titled, *Our Common Future*, a definition of sustainable development was given as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This report noted the humanities dependency upon economy, society, and the environment for health and well-being. The foundation of this definition is still at the forefront of research and development although many variations have been emphasized across disciplines.

Confronting the theory of sustainable development is the proven human behavioral pattern of time inconsistency and hyperbolic discounting (Frederick et al., 2002). In summary, this is the idea that people tend to decrease the value of a good or service received in the future. For instance, a hundred dollar bill today is may be more desirable to a person than a hundred and fifty dollars five years in the future. Thus, this is the principal behind the discounted-utility model proposed by Paul Samuelsson in 1937 and used by lending institutions since to determine interest rates and loan durations (Overton & MacFadyen, 1998). Transferring this ideology to how we value the future of the planet is illuminating in how business decisions are made. For example, if we valued the health and well-being of future generations as being equal to our own health and well-being then policy and programming would confront the overuse of non-renewable resources more aggressively (Pearce et al., 2003). The same goes for the use of nonrenewables in agricultural production. There is no doubt that sustainable management may be at a financial cost for both current and future generations but they will deliver high returns for future generations (Schilling & Chiang, 2011).

Those studying multifunctional agriculture have been advised to integrate sustainability principals into research objectives (Renting et al., 2009). The acknowledgement that agriculture produces many commodity and non-commodity outputs has been seen as a path to policy creation that emphasizes rural development goals and agricultural initiatives in the United Kingdom (Renting et al., 2009). A contingent evaluation in the United States examined how much American taxpayers were willing to pay for such policies, the results concluded that individual tax payers were willing to spend an average of $515 a year to support multifunctional agriculture policy (Moon & Griffith, 2011). Although desirable by the public, economic outcomes of the policies are contradicting in results (Marsden & Sonnino, 2008; Heringa,et al., 2013).

Research into UK multifunctional policies suggests that while the State is promoting the regionalism and rural development initiatives of a post-productive society the goals are in conflict with the State's support of conventional agricultural systems (Marsden & Sonnino, 2008). The author calls for a review of the multifunctional agricultural policies to become more integrated into the prevailing market resulting in better financial gains for farmers of the region. Another study on multifunctionality in the Netherlands suggests that the low-input nature of the policies requires more physical labor on local landscapes (Heringa et al., 2013). The switch from high-input to low-input has increased the demand for labor in regions thus having a positive, oftentimes variable, impact on the economies of the region. In some areas where labor is scarce, moving to this type of agricultural system may increase the pressures for farmers to find gainful employment.

It is important to recognize the difference between sustainability as defined in *Our Common Future* (Brundtland et al., 1987) and classic economic sustainability. When an actor is concerned only with maximizing their profits in agriculture it comes at a great cost to the sustainability of future generations. Take P for example. This mineral, which is used in synthetic fertilizers, is mined from distant finite reserves. For a profit-maximizing farm, use of this fertilizer will increase yield, until the plant cannot absorb the excess applied or until the reserves are entirely depleted. As with any non-renewable resource, the use of P today means increased profits now at future costs. In addition, the use of this resource can contaminate a public good, clean water. When clean water is compromised it is at the cost of future generations. As noted before, sustainability in agriculture can be expensive but it will help alleviate the environmental struggles of future generations.

This study will analyze the inclusion of multiple objectives in defining just distribution of funding and outreach for P runoff reduction in the State of Vermont. At the farm scale, we will evaluate the spatial representation of agricultural best management practices already implemented (without financial incentive), economic data, and the amount a principal operator farms to connect with their community. The three-pronged assessment—environmental, economic, and social—will form the basis of a sustainability score that may be used to prioritize farms based upon their existing performance.

Food Security and Sustainable Regional Food Systems

In the 21st century, researchers are calling for a regionalization of food systems to confront potential food security threats (Hinrichs, 2013). Recent literature suggests the US dependency on the global food system may become compromised after 2050 due to climate change impacts (Takle et al., 2013) amongst other variables. In the State of Vermont, 12.6% of households are considered food insecure and 6% of households are considered to be very low food secure households (Parker, n.d.). Food security as defined by the FAO in 1981 is the production of enough food to feed a nation or region in the situation of a crop failure or trade difficulties. This definition is enhanced by Hamm & Bellows 2003 by defining food as it pertains to security; “a condition in which all community residents obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes community self-reliance and social justice.” These two definitions can be used to understand the potential food security benefits of broadening, deepening, and re-grounding agricultural activity within local/regional food systems (Van der Ploeg et al., 2003). This multifunctional classification scheme categorizes the manner in which a farm departs from conventional agriculture models on their farm (Renting et al., 2009).

The distance a food can travel while still being deemed local is a complex topic of current food system research (Martinez et al., 2010). The most definitive geographical distance was declared by U.S. Congress in the 2008 Food, Conservation, and Energy Act.

The act stated a maximum distance a food product could be transported while being labeled local or regional was 400 miles from the farm origin or the state in which the product was produced. For the remainder of this paper local and regional will be used interchangeably to represent 400 miles from the origin of food production or the state of origin. In relation, these systems are built upon short supply chains in comparison that the longer chains in the conventional system (Tregear, 2011). Thus, we may also prescribe the word use of 'alternative' to characterize the local/regional system. Much of the literature has cited an enthusiasm for the positive impacts the alternative food system has on rural development (Renting et al., 2003). There are still criticisms of local/regionalization of food. Some of these arguments include the social inequalities that exists in California alternative systems (Allen et al., 2003) and that shorter supply chains may not be as energy efficient or reduce greenhouse gas emissions as well as the conventional system (Edwards-Jones et al., 2008). With the complexities being known, we will frame a primarily alternative food system as being desirable for the State of Vermont.

A quantification of the volume a farm sells to their local/regional food system can be realized by operationalizing the broadening, deepening, and re-grounding framework provided by Van der Ploeg to categorize multifunctional activities (Van der Ploeg et al., 2003; Liang et al., 2012). Broadening economic activity is a farm's creation of alternative products and services. These can be accounted for by measuring agri-tourism and value addition. Deepening occurs when a farm produces a good or service that meets the needs of the consumer and can be measured by examining direct sales. Re-grounding is understood as a refocusing of household activities, this can be investigated by evaluating the amount a farm family works off the farm. The alternative market channels investigated to determine the degree of multifunctionality are agri-tourism, value addition, direct sales, and off-farm income. These regional markets are considered alternative in comparison to conventional markets that are deemed much more efficient and produce a large quantity of food product for the national and global markets. Examining the markets-sold-to is essential for classifying a farm as either alternative or conventional in their processes.

Measuring the impact that alternative agriculture has on a sustainable food system involves an understanding of economic contribution along with social and environmental contribution. From an economics viewpoint, local food systems can provide employment to rural workers, help underserved populations gain healthy food access, and keep money circulating within the area (Mills, 2012). Socially, alternative food systems may play a role in developing quality of life, culture, and community (Armour, 1990; Mills, 2012). Using labor-intensive practices in agriculture may contribute to the development of a farmers' ability to manage, monitor, and evaluate the environmental stewardship (Herzon & Mikk, 2007). These indicators although seemingly independent are all-together correlated with one another, which may evoke funding and outreach opportunities, as discussed in the following section.

Leveraging Outside Funding Sources

The prioritization of farms based upon their environmental, social, and economic measurements may be useful in generating additional funding and outreach outside of the

Agency of Agriculture Food & Markets. For example, because eutrophication of public waterbodies is both an environmental and agricultural issue, the Agency of Agriculture Food & Markets is working closely with the Agency of Natural Resources to leverage water quality resources.

This tactic has been used in the creation of funding for the Working for Water (WfW) Ecosystem Service project in South Africa. The WfW program was implemented in an effort to control the amount foreign plants that were spreading across their landscapes (Turpie et al., 2008). The water supply in South Africa was suffering due to the invasive plants massive water intake. In addition to the decline of water supply, the unemployment rate in the country was high and people were looking for employment. By combining economic objectives with water supply initiatives they created a program that hired from the pool of unemployed citizens. These employees could create their own companies that contracted with private-landholders to manually remove the invasive species from properties of concern. The WfW program morphed depending upon the resources it needed. For instance, if funds became available for economic development then they would market themselves as such. Likewise, if funds were available for water supply issues then they would conform their program to meet the requirements. The State of Vermont may be able to use the same tactic to leverage funding and resources from other agencies within the state.

The Department of Tourism and Marketing is housed within the Vermont Agency of Commerce and Community Development. This department associates the Vermont Brand "… with environmental quality, "green values," local, strong community centers, an active agricultural economy and world class, four-season recreation." This statement appears to be challenged by the State of the Lake report which details many beach segments on Lake Champlain being closed, multiple times, due to both E.Coli issues and Blue-Green Algal blooms (Evans, 2015). In addition, Lake Champlain waterfront property values have been declining in Missisquoi Bay, due to the concentration of eutrophication in the area (Associated Press, 2015). The water quality issues within the state of Vermont are sure to have a significant impact on the economy in reference to recreation and tourism in the local waters. For this reason, monies may be available to farmers that contribute to the agri-tourism industry within the state for implementation of agricultural best management practices.

As mentioned previously, it is up to the State of Vermont and its citizens to determine which variables they want to emphasize in building a multifunctional sustainability score. If the amount a farm connects to the community does not resonate with the agriculturists and the citizens then it should not be included in the analysis or it should be weighted less. The social connectedness indicator in itself is difficult to emphasize as farmers that are naturally introverted and enjoy their solitude on their land should not be prioritized less than the social sort. In this way, using a socio-economic indicator may be desirable. Intrinsically, the economic indicator measured in the building of this multifunctional sustainability score also measures social connectedness by way of direct sales, agri-tourism, and working off the farm.

Pay for Performance

The prioritization of farms for funds and outreach through Act 64 places an emphasis on farms that are considered critical sources of P. State funds from the Clean Water Act will be dispersed to these farms first for the implementation of practices outlined in the certification process such as submitting a phosphorus-based nutrient management plan, education classes, and the application of Required Agricultural Practices (RAP). This conventional form of subsidizing has been under scrutiny as a financially inefficient way to reduce non-point source pollution from agriculture (Isik, 2004). Arguments include "… they (a) are not directly targeted at nutrient pollution (i.e. as a nutrient tax would be) but for practices that often have unknown or highly uncertain nutrient reduction efficiencies; (b) are not targeted geographically to watersheds and land uses that could represent the greatest return for each dollar spent; (c) are subject to the vagaries of public budgeting, and; (d) reduce flexibility of polluters to adopt practices that may be more effective than the list of approved BMPs (Talberth et al., 2015)." In addition, existing subsidies have been under scrutiny for their lack of aid in reducing non-point sources of pollution from agriculture (Shortle et al., 2012). A case of non-point source nutrient pollution, of management interest is the Chesapeake Bay an estuary of the Atlantic Ocean, bounded by the Northeast of the United States.

The largest estuary in the United States has been troubled by water eutrophication for the past one-hundred years (Shortle et al., 2012). Much like Lake Champlain, the estuary has been deemed impaired by the Environmental Protection Agency and a Total Maximum Daily Load was set for several nutrients including P (US EPA, REG 3). Prior to the establishment of the TMDL the State of Vermont worked towards cleaning their waters through incentivizing the implementation of best management practices through subsidies. The process has been very costly and inefficient for the States bordering Chesapeake Bay. In an effort to propose an alternative policy strategy Talberth et al., (2005) studied the impacts of a Pay for Performance (PFP) incentive program in the Chesapeake estuary basin.

PFP incentives are based on the actual performance of an agricultural unit in reducing nutrient runoff from their parcel. This scheme allows the farmer to use their knowledge set to build a program that works best for their land and production. This is similar to the Payment for Ecosystem Services concept that essentially has beneficiaries paying polluters for reducing their impact on a public good (Fisher & Turner, 2008).

To compare the costs and benefits of business-as-usual as opposed to a pay for performance policy in the Chesapeake Bay, a spreadsheet-based model was used to determine the tradeoffs between each policy approach (Talberth et al., 2005). The study used 14 best management practices, nutrient reduction efficiencies, total costs, and total public costs as variables. In the PFP scenario the reduction was based upon optimization of BMPs whereas in the business as usual the reduction was based upon the enforcement of a set of BMPs. The major finding of this study was the PFP policy generated greater cost savings with the same amount of reduction efficiency when nutrient reduction was held constant. Additionally, when costs were held constant in a scenario, the PFP policy delivered two to three times the amount of nutrient reduction. The authors of this paper suggested further examination of PFP strategies to reduce nutrient runoff in the

Chesapeake Bay. These findings support the arguments of Talberth et al., (2015) in the previous section. In the Lake Champlain basin, PFP may be of interest not just for environmental practices but also for social and economic performances as well.

Research Question and Objectives

The Clean Water Fund was created to support the implementation of water quality initiatives in various sectors throughout the State of Vermont. The resources within the account are limited; therefore careful prioritization of farms for outreach is essential. In this paper a prioritization methodology is presented using theory from the sustainable multifunctional agriculture literature. In the analysis, Geographic Information Systems (GIS) software was used to map environmental practices on twelve farm landscapes to generate a spatial representation of environmental stewardship that was then translated into an environmental score. This environmental score was combined with social and economic data to prioritize farms based upon their multifunctional sustainability. This ranking methodology may be useful for the State of Vermont in determining the prioritization of Clean Water Fund resources using farm sustainability measurements.

The information derived from this analysis may be used to prioritize farms using variables that highlight an individual farm's contribution towards increasing regional food security and similarly, a sustainable regional food system. The measurement of sustainability variables –environmental, social, and economic—creates evidence of sustainability at the farm-scale that can be leveraged to secure outside funding for rural economic development initiatives. Lastly, data generated through this study may be used to build a spatially defined performance-based incentive program for farmers looking to be rewarded for their on farm phosphorus runoff reduction efficiencies.

The goal of this study is to prioritize farms based on their current performance – economic, social, environmental—activities. Thus, the research questions and objectives are as follows:

RQ: Which Vermont farms should be prioritized to receive funding and outreach for P reduction under the new Total Maximum Daily Load (TMDL) standard set forth by the Environmental Protection Agency (EPA) by valuation of multifunctional sustainability performance.

RO1: To spatially define the area of land under best management practice in relation to the total area of land that could potentially be under best management practice for each farm.

RO2: To quantify the amount the principal operator farms to connect with the community.

RO3: To quantify the proportion of alternative markets sold to as a proportion of total markets.

RO4: To create a sustainability score for each farm based on data collected in RO1, RO2, and RO3. Use the sustainability score to prioritize farms according to multifunctional sustainability.

Data[2]

Small multifunctional farms were selected at the target population for this study. In addition to food and fiber, these farms produce non-commodity outputs that have can have positive or negative impact on society (UNCED, 1992). Examples of multifunctional activities (MFA) are: building social capital through direct sales, stewarding the environment by using agricultural best management practices, and/or creating local economy by selling food and fiber within the region. These three practices are the core of what this paper discusses. For this study, we will be looking at the actor-oriented approaches to multifunctional agriculture by examining the 'broadening', 'deepening' and 're-grounding' of agriculture in society (Van der Ploeg et al., 2003).

Farms were approached for inclusion in the study if a majority of their sales came directly from the consumer, agri-tourism, off-farm income, or value added products (Liang et al., 2014). Multifunctional farms were targeted for this analysis due to their high level of interaction with the community. We are assuming an increase of exposure to the community may have an impact on the functional, emotional, social, epistemic, and conditional values a farmer associates with adopting BMPs for P runoff reduction. Future studies will examine medium to large scale conventional farming within the state to indicate differences in sustainability as measured in this study.

The sample was accumulated from an array of food networks in Chittenden County although farmers represent several regions within Vermont. The first collection

[2] See Appendix B for the sample profile.

of contacts was at the Vermont Vegetable and Berry Association annual meeting in the spring of 2015. The second collection of contacts was from the Rutland Food Area Guide (RFAG). The RFAG lists the small and medium sized farms in Rutland county, their contact information, what they produce, and whether or not they're open to visitors. Contacts from these two groups were approached to become part of the study by an initial phone call with a follow-up mailing of the survey instrument.

From the first round of recruitment we mailed questionnaires to sixty farmers with thirteen of them returning a completed survey. We then started offering an $80 compensation for filling out the survey and participating in an hour-long farm visit by a research assistant. With this compensation we gained five participants from the original sample. From there we decided to contact farmers engaged at the Burlington and Winooski Farmers' Markets, adding an additional six participants to the sample.

If farms did not own any of their land, owned less than ten acres, or were not able to be interviewed on their farm by the research assistant then they were not included in the study. Therefore, the final sample size for this study is twelve farmers. The production of each farm is broken down as follows: two farms in animal production, three farms in maple production, three farms in vegetable and animal production (mixed), and four farms in vegetable production.

A limitation of this study is the exclusion of the dairy sector in the sample. Crops supporting the Vermont dairy industry include hay and haylage, grass silage, and greenchop, corn for silage and corn for grain. Land designated for the dairy industry covers 900,000 acres or 80% of the total farm acreage in the State of Vermont (USDA Census of Agriculture, 2012). Evaluation of different types of farm production is warranted as P can build up on other agricultural soils and Act 64 does not discriminate between production types.

P build-up in vegetable soils in Vermont was investigated by soil test results from a randomized sample of forty-eight vegetable farms. The data was collected and analyzed by the University of Vermont Agriculture and Environment testing laboratory. Of these farms, twenty-three reported high or excessive levels of P. That is approximately 48% of the samples included in this independent study. Therefore, we can predict that vegetable production in the State of Vermont may be contributing to P runoff. As mentioned previously, this may be a product of either over application or farm ownership transfer.

Table 8[3]: Farm by Production Type

Farm ID Number	County	Acres	Production
1	Addison	100	Animal
2	Addison	101.5	Animal
3	Rutland	600	Maple
4	Rutland	180	Maple
5	Chittenden	74	Maple
6	Rutland	25	Veg. & Meat
7	Chittenden	250	Veg. & Meat

[3] See Appendix B for the sample profile.

8	Washington	7.5	Veg. & Meat
9	Washington	158	Vegetable
10	Franklin	54	Vegetable
11	Addison	280	Vegetable
12	Rutland	44	Vegetable

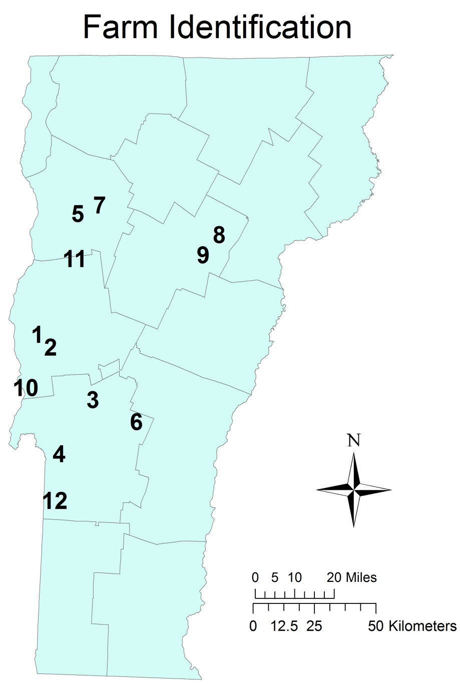

Figure 4: Brown (2016) Spatial Location of Farms in Sample

Act 64 does not distinguish between different types of agricultural production, whether it be crops for animal feed or vegetable production. Instead, Act 64 has created sets of required agricultural practices (RAP) based on the size of the farm. According to the State there are three designations of farms: the small farm operation (SFO), medium farm operation (MFO), and the large farm operation (LFO). Each type of farm operation will need to complete a certification declaring implementation of set RAP starting on July 1st, 2017. An additional permit is required for Concentrated Animal Feeding Operations (CAFO) that are either MFO or LFO in size. Proposed RAP's include a field-to-field 590 Nutrient Management Plan, vegetative buffer zone, animal mortality management, cover cropping, reduced tillage, exclusion of livestock from waterways, and a compliance inspection within five years (Vermont Agency of Agriculture, Food and Markets, 2015). The SFO's must complete a required education course for farmers and annually submit a report of compliance to the State of Vermont.

Economic Data

To develop an economic indicator of multifunctional contribution to regional food systems a ratio was calculated depicting the percentage of alternative markets sold to in relation to total markets. The economic score was measured in the mail survey by quantifying total sales from working off the farm, agri-tourism, direct sales, and value-added products. As financial information is sensitive, respondents were able to report either their gross sales or volume of sales for each of the categories. The construct used to measure off-farm income was: estimated total money received or hours worked in 2014 by the principal operator, spouse/partner, other household member 1, and the other household member 2. Agri-tourism was measured by: estimated total money received or number events held in 2014. The events listed on the survey were educational events, outdoor recreation, accommodation and food services, festivals and events, or other. Direct sales were measured by: estimated total money received or number of accounts in 2014. The types of markets listed were farm stand, community supported agriculture, farmers' market, local hospitals, local schools, local restaurants, local food cooperatives, and local independently-owned groceries. The conventional markets listed were corporately-owned food stores and distributors. As mentioned previously and in the methods section, the conventional markets were then broken down according to distance from place of origin. Any food that traveled over 400 miles via wholesale processing was considered conventional. Value-added was measured by: estimated total money received and the number of products belonging to the company in 2014. The categories listed on the survey include fruit preserved products, dairy products, pickled fruits and vegetables, alcohol, wool and mohair products, maple products, baking/cooking condiments, aquaculture, forest products and by-products, fermented products, and fruit/vegetable value-added products.

Local food systems can provide employment to rural workers, help underserved populations gain healthy food access, and keep money circulating within the area (Mills, 2012). A recent study examined the role of a regional food system in the State of Florida to conclude that 20.1% of household food purchases were within the regional system of which supplied 183,625 jobs and $10.47 billion dollars in value-added revenue (Hodges et al., 2014). This calculated contribution was greater than in other similar studies outside the State of Florida. The localization of food systems is hypothesized to contribute towards the creation of healthy rural economic development (Banks & Marsden, 2000).

Social Data

The social indicator was constructed from literature on the incorporation of social impacts in planning and evaluation. Measuring this variable is oftentimes difficult to do given inherent complexities and the inconclusive definitions throughout the literature (Vanclay, 2002). For this reason, this study uses the clear framework provided by Putman (1993.) In this conceptualization there is an emphasis placed upon: (1) farmers connection with other farmers (bonded relationships), (2) farmer connections with the community (bridged), and (3) farm connections with institutions. Because social information is difficult to quantify using a simple measurement on a survey, this study relied on interviews to determine the amount of connectedness a farmer had with other farmers, their community, and institutions. A three-point scale ranging from 0, 0.5, 1 was used by the research assistant to determine the contribution from each farm to the societal make-up of their community.

Environmental Data

Common agricultural practices were used in this study as a proxy for general environmental stewardship on a farm. We used a suite of Best Management Practices (BMPs) taken from the Lake Champlain BMP Scenario tool (Tetra Tech, 2015) to determine the environmental score. Added to this list was a land conservation practice that included all area kept under natural forest on the agricultural parcel. The list of BMPs and their descriptions is given in Table 10.

Table 9: Best Management Practices

Best Management Practice	Description
Cover Cropping	Establishing a seasonal cover on annual cropland for soil erosion reduction and conservation purposes. Cover cropping would consist of a crop of winter rye or other herbaceous plants.
Changes in Crop Rotation	Standard rotations. For example, rotations of corn to hay and rotations of corn to soybean.

Alternative Manure Incorporation	Applying liquid manure below the soil surface.
Conservation Tillage	Any tillage and planting system that leaves a minimum of 30% of the soil surface covered with plant residue after the tillage or panting operation (for example, reduced till, no-till)
Reduced Phosphorus Manure	A 20% reduction of the total Phosphorus content being applied to fields through either manure or fertilizer.
Grassed Waterways	Stabilizing areas that are sensitive to erosion by establishing grass-lined swales.
Grassed Riparian Buffers	Areas of grasses or shrubs (which may include trees) located adjacent to ponds, lakes, and streams that filter our pollutants from runoff.
Fencing Livestock Inclusion	Exclusion of livestock from waterways and stream banks by installing fence.
Barnyard Runoff Management	Exclusion of clean water runoff from the barnyard and heavy-use area and management of the remaining runoff in a way that minimizes pollution.
Crop to Hay	Permanent conversion of crop land use to hay.
Field Ditch Buffer	Grassed strips along the drainage ditches that filter our pollutants from the adjacent land runoff.
Land Conservation	Area of land kept in forest

The environmental sustainability score was derived from a combination of sources: a mail survey, farm visit, and publicly available geographic information. At first, we collected quantitative information from a mail survey. Respondents were asked to declare whether they were 'Not Willing to Adopt,' 'Willing to Adopt,' 'Already Adopted BMP' or if the BMP is 'Not Application on [the] Farm' for each of the listed BMPs in Table 10, with the exception of conservation.

In coding the responses, we collapsed three categories down to two, 'Already Adopted BMP' and 'Has Not Adopted BMP'. The second category was formed from condensing the 'Not Willing to Adopt' and "Willing to Adopt' as both of these responses signify that the farmer has not actually adopted the BMP at the time of the survey.

If a particular BMP was 'Not Applicable on the Farm' then we did not spatially represent the practice as it did not occupy land cover. The principal operators filling out the survey were asked to assume that there would be no financial incentives for implementation and management of the BMPs.

The second source of environmental information was gathered from on-site visits conducted by the researcher. The purpose of the visit was to understand the spatial representation of their production and how it related to the BMPs measured in the survey. In addition to surveying the land, the researcher gathered information on challenges facing the farm, future opportunities, and current farm activity. If the farm filled out the survey and engaged in the field visit then they were rewarded with $80 to compensate them for their time.

Thirdly, geographic information was collected using public data and analyzed using Global Information Systems (GIS) software. The E911 addresses, cadastral parcel boundaries, and orthographic imagery allowed the researcher to identify and digitize the spatial extent of all the BMPs that could be implemented on the farm. The research objective for creating the environmental sustainability score is to spatially define the area of land under best management practice in relation to the total area of land that could potentially be under best management practice for each farm.

Empirical Methods

For the economic sustainability calculation, we calculated the percentage of multifunctional markets sold to in 2014. The percentage was calculated by adding the total amount of money made or the total amount of markets sold to. We then added up the sales or markets, excluding the sales outside the region using conventional processing. A percentage calculation was created by dividing the total amount of money or volume of sales by total amount of multifunctional money made or volume of multifunctional product sold. Each farms' economic sustainability score is listed in Table 10.

Table 10: Economic Sustainability Score

Farm Identification Number	Economic Sustainability Score
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	0.86
10	0
11	1
12	0.97

The social sustainability score was determined by the researcher and data collected in the mail survey. Using literature, the goal was to assign a value to the farm for their farm-to-farm, farm-to-community, and farm-to-institution connectedness. The researcher used qualitative information attained in the field interview to assign a value from 0 – 1 for the farm-to-farm value and the farm-to-institution value. In the mail survey, information was collected from answers to the statement, “I farm to connect to the community.” The sample was asked whether they “agree,” were “neutral,” or “disagree” with the statement. When coding, agree was assigned a value of 1, neutral 0.5, and disagree 0. This value was used for the farm-to-community indicator. All three values were averaged for a final social sustainability score.

Table 11: Social Sustainability Score

Farm Identification Number	Farm to Farm (Bonded)	Farm to Community (Bridged)	Farm to Institution (Linked)	Social Sustainability Score
1	.5	1	1	.8333
2	1	.5	1	.8333
3	1	.5	1	.8333
4	1	1	1	1
5	.5	.5	0	0.333
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	.5	1	.5	.6666
11	1	1	1	1
12	1	1	1	1

The environmental score was developed using ESRI ArcMap Geographic Information Software. The total project was stored in a personal geodatabase which included a feature data set for each farm. This feature dataset was used to archive the relevant parcels, ortho-imagery, and the digitized spatial representation of agricultural best management practices. Farms were identified using the E911 buildings data from the Vermont Center for Geographic Information (VCGI). The state-scale data was cut to the extent of the farms county and then using "Select by Attribute" was located by the provided street address. Using the cadastral parcels we selected the parcels perceived to be owned/rented by the farm under analysis. From the selection of parcels we created a feature class, titled 'Parcel_(farm name).'

For each BMP that could be implemented on the farm we created a feature class '(farm name_BMP).' Then, each feature class was digitized using the 'Editor' tool to spatially represent the extent of the applicable BMP on the landscape contained within the boundaries of the farm or 'Parcel_(farm name).' The criteria for digitizing each practice is given in Table 4. If multiple BMPs represented the same space, such was the case with fields under cultivation, then we used the 'Copy Features' tool to duplicate the original polygon. The riparian buffer polygons were created from the State of Vermont hydrology data clipped down to the '(farm name)_parcel' boundary. Using the 'Buffer' tool to designate a 25 foot polygon surrounding surface water located on the property led to the generation of the '(farm name)_riparian' feature class.

Each feature class that was digitized could contain multiple polygons representing the same BMP. To simplify the data, the researcher used the 'Dissolve' tool to generate one polygon record for the BMP being considered. After dissolving the data for each practice we were able to view the total area represented in the polygon. The area of all the BMP feature class polygons will be used to create the environmental sustainability score of each farm.

Table 12: Criteria for Digitizing the Spatial Extent of BMP

Best Management Practice	Feature Class	Criteria
Cover Cropping	(farm name)_CC	All of the fields under cultivation.
Changes in Crop Rotation	(farm name)_CR	All of the fields under cultivation.
Alternative Manure Incorporation	(farm name)_AMI	All of the fields under cultivation.
Conservation Tillage	(farm name)_CT	All of the fields under cultivation.
Reduced Phosphorus Manure	(farm name)_RPM	All of the fields under cultivation.
Grassed Waterways	(farm name)_GW	Swaths of grass that were in areas with steep slopes.
Grassed Riparian Buffers	(farm name)_Riparian	A 25 foot area on either side of a stream/river, or around a pond/lake.
Fencing Livestock Exclusion	(farm name)_FLE	A 25 foot area on either side of a stream/river, or around a pond/lake.
Barnyard Runoff Management	(farm name)_BR	The spatial extent of the barn.
Crop to Hay	(farm name)_CH	Specific fields that had been converted to hay production.
Field Ditch Buffer	(farm name)_FDB	A 25 foot area on either side of identified field ditches.
Conservation	(farm name)_C	All forested areas on the property.

At this point, the area of land that has a potential of being managed for P runoff reduction is known. The next step is determining whether each practice has, or has not, been implemented at the farm. Once this is known, then we can calculate the environmental sustainability variable by dividing the amount of land under BMP management by the total applicable land.

Table 13: Example Best Management Practice Table

SHAPE_Length	**SHAPE_Area**	**AdoptedBMP**	**TypeBMP**	**Farm**
1874.5169269932	36094.311692585	1	CoverCrop	2
5401.91587945661	335709.240539802	1	Conservation	2
1874.5169269932	36094.311692585	1	CropRotation	2
1874.5169269932	36094.311692585	0	ConservationTillage	2
871.780608785244	13728.2911645107	1	CroptoHay	2
466.132676012717	783.29079052496	1	FieldDitchBuffer	2
1319.95869975929	6488.48312646942	1	GrassedWaterways	2
6839.62151737439	76391.22286199	1	RiparianBuffer	2
1874.5169269932	36094.311692585	0	ReducedPhosphorousManure	2

Using Microsoft Access, three columns were added to the attribute table of each BMP feature class: AdoptedBMP, TypeBMP and Farm. To compress all the BMPs into a common place, a new table was created for the farm entitled, '(farm name)_Final'. In the new table new columns were made including: Shape, Shape_Length, Shape_Area, AdoptedBMP, TypeBMP, Farm. Using the 'Append' tool in Microsoft Access query design the BMPs were moved from individual records to a cumulative of records in the final table for the farm. At this point, all the BMP feature classes and their columns were consistent. The 'AdoptedBMP' field was then filled with either a '1' indicating the BMP was implemented or a '0' indicating the applicable BMP was not implemented on the farm. Table 13 represents the final table including the spatial area of each applicable BMP and whether or not the practice has been adopted per the '1' or '0' entry under 'AdoptedBMP.'

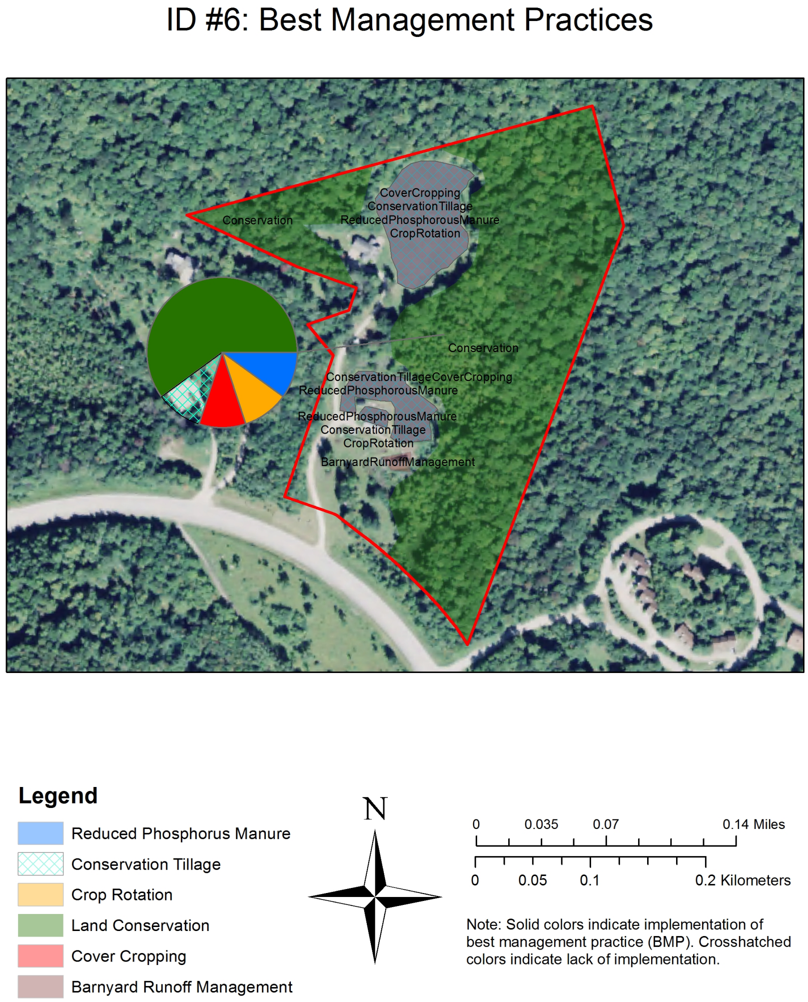

Figure 5: Brown (2016) Spatial Representation of BMPs on Farm ID #6

From the final table for each farm we were able to calculate a proportion of land under BMP management as a fraction of the land that could potentially be under best management. This was done by adding the SHAPE_Area of each practice implemented on the farm, designated by a '1,' and then dividing this by the total SHAPE_Area of all the BMPs listed. This proportion represents the environmental sustainability variable for each farm, the results are given Table 15.

Table 14: Environmental Sustainability Score

Farm Identification Number	Environmental Sustainability Score
1	.61
2	0.99
3	0.97
4	0.97
5	1
6	0.9
7	0.91
8	0.77
9	0.88
10	1
11	1
12	0.49

The environmental score is represented in Figure 5 as the ratio of solid colors (implemented best management practices) to crosshatched colors (non-implemented practices). Noticeably, forest conservation is the dominant practice in regards to its spatial extent. Additionally, each best management practice is associated with its own P runoff reduction efficiency (Tetra Tech, 2015). Therefore, we cannot conclude that just because a practice covers the most surface area, it is most affective at reducing runoff.

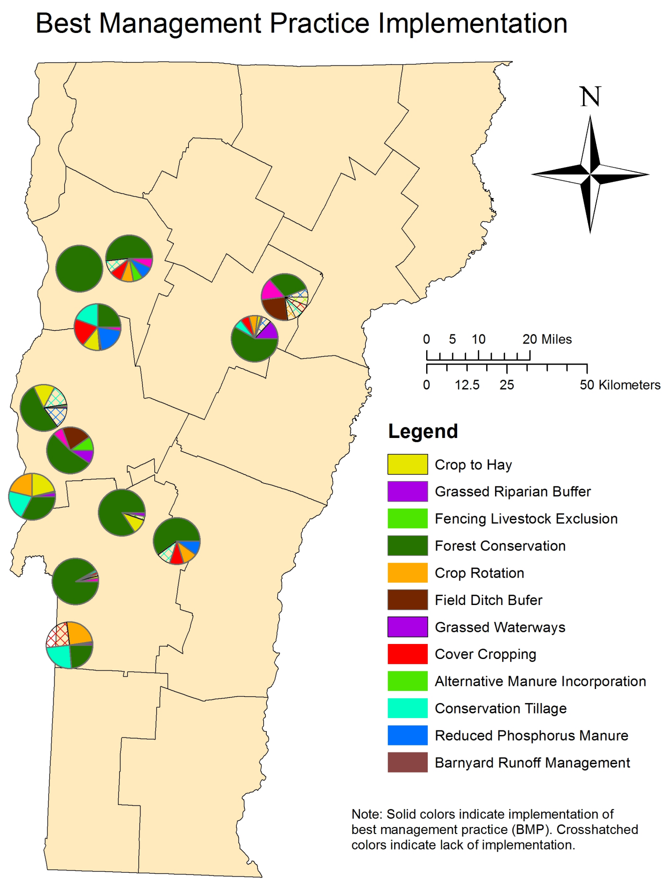

Figure 6: Brown (2016) Farm-Scale Best Management Practice Implementation

Results

To generate the overall multifunctional sustainability score we added the economic, social, and environmental sustainability score. This created a ranking of farms on a 0-3 scale. Keep in mind, the farms used in the sample are already multifunctional in their structure therefore the results are skewed towards sustainability.

Table 15: Final Multifunctional Sustainability Score

Farm Identification Number	Economic Sustainability Score	Social Sustainability Score	Environmental Sustainability Score	Multifunctional Sustainability Score
1	1	1	0.61	2.61
2	1	0.5	0.99	2.49
3	1	0.5	0.97	2.47
4	1	1	0.97	2.97
5	1	0.5	1	2.50
6	1	1	0.9	2.90
7	1	1	0.91	2.91
8	1	1	0.77	2.77
9	0.86	1	0.88	2.74
10	0	1	1	2.00
11	1	1	1	3.00
12	0.97	1	0.49	2.46

Figure 6 visually represents each farms' location on within the state and their associated environmental, social, and economic scores.

Mulifunctional Sustainability of Farms

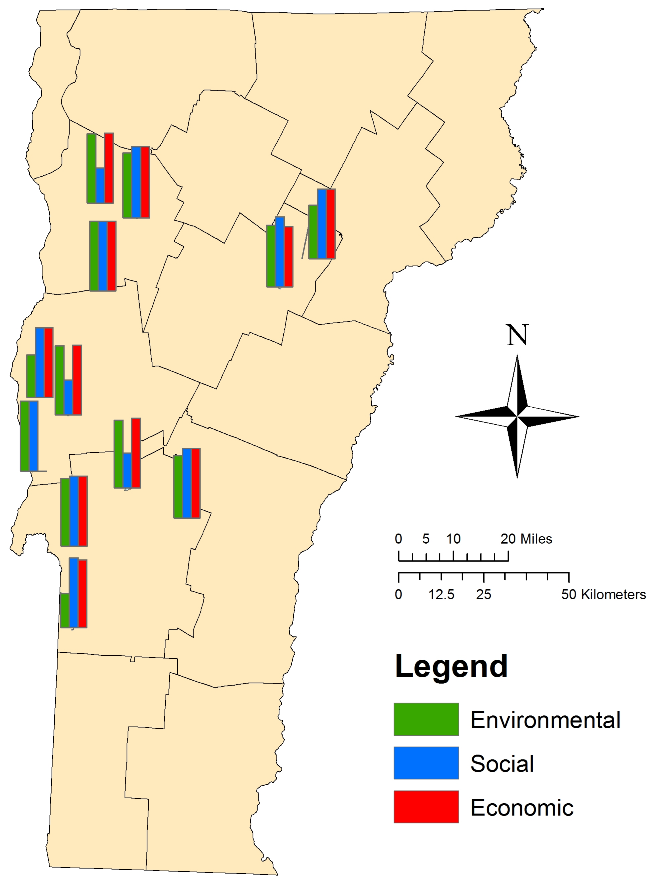

Figure 7: Brown (2016) Farm-Scale Multifunctional Sustainability

Conclusions

The State of Vermont is working with the Environmental Protection Agency to control the amount of P running off landscapes into Lake Champlain and other impaired waterbodies. Through the process a Total Maximum Daily Load was established with greater demands then the initial TMDL. Therefore, great reform is underway on several types of land uses within the State of Vermont. Land under cultivation is particularly of interest as reports have found that the agricultural sector contributes to 41% of the P loading from the State of Vermont (Lake Champlain Basin Program, 2015). Act 64 was enacted to address regulations and management of programming to support reductions via funding and outreach allocation to various farms throughout the State. Money for implementing this program is limited thus careful considerations for prioritization is essential for getting a great return on money invested in P runoff reduction. This study used multifunctional sustainability literature to create a method for prioritizing thirteen farms for assistance.

We were able to create a prioritization ranking that revealed what farms should be prioritized to receive funding and outreach for P reduction under the new TMDL standard set forth by the EPA by valuation of multifunctional sustainability. The ranking scheme presented in this paper is meant to reward farmers according to the implementation of BMPs on their farm. This type of ranking may not be desirable in mitigating phosphorus runoff reduction in the short-term as efforts must be focused on the critical source areas of phosphorus. The value in Pay for Performance strategies may be realized in a long-term strategy to reduce phosphorus by rewarding those that do so the most. Now, it is not realistic to approach policy with long-term solutions to short-term problems but there may be a compromise that benefit all parties involved.

The variables used in the ranking were based on a farms actual performance in regards to environmental stewardship, community involvement, and sales in the regional food system. Measuring these variables may create leveraging opportunities for outside funding to support both P runoff goals and economic development initiatives. For instance, Farm #1 has perfect economic and social scores but lacks in environmental stewardship, these measurements may appeal to Vermont Department of Economic Development as the farm has a stake in the community and creates local economy. Incentivizing the farm to reduce their nutrient runoff through paying for performance programs through the Department of Economic Development may be strategic for them as farms that do not comply with the new standards can have their 'land use' revoked due to non-compliance. This would hurt the economy and community if such a farm had to close their doors to business. The emphasis the State of Vermont wants to put on each of these variables is up to long-term goals of the State and their intentions for agriculture.

This study could be enhanced through weighting variables to place importance upon both time and agricultural goals. For instance, the economic, social, and environmental scores should reflect the amount of time the farm has been working on the land as a seventh generation farm may have a temporally magnified impact on the local economy, society, and their land in relation to a first generation farm. Also, the goals of the state should be declared before constructing the prioritization system. This is most evident in considering the social variable. Not all farmers are embedded into farmer groups, their community, or institutions although they may produce for the local economy using environmentally sound practices. This farmer should not be punished for his introverted ways, therefore careful consideration is necessary in considering the social variable. Weights should reflect the priorities of the agricultural sector.

In addition, a farm's proximity to surface water and drainage into ground water is integral in the understanding of nutrient transport off a farm and how much of an impact a particular farm has on downstream communities. For instance, a farm that is located on a river with sandy soils is predicted to have a higher rate of nutrient transport and overall impact on the quality of water than a farm that is located in a forest setting, on a hill, miles away from any surface water. Information on the waterbodies in which the nutrients from the farm drain into is significant in determining overall impact as well. If a farm drains directly into the Mississquoi Bay of Lake Champlain where P eutrophication is most dense, the farm would have a greater impact than draining into a pond in Eastern Vermont that can assimilate the added P.

To carry out this analysis, a literature review would need to be conducted to find out a field's desirable distance from a surface waterbody, how soil types influence the transport of nutrients, and the impairment of local waterbodies. A polygon vector file would be downloaded from the Vermont Center for Geographic Information with spatial representations of geographic soils. From the same source, a raster file denoting State elevations will be downloaded. Then, line vector hydrology network data would be downloaded from the National Map. Once the appropriate files have been downloaded, using the spatial selection tool, an analysis would be performed that would select all above-ground water networks within a determined distance from the farm (the distance is determined in the literature review). A route hydrology analysis will then be performed using the elevation as a cost. Therefore, the analysis will conclude with the most direct hydrological route that uses minimal elevation cost (or upward mobilization). Once the drainage route is determined, the environmental variable can be weighted according to the soil type, distance to a surface waterbody, and the impairment of the waterbody the network drains into. This will provide a more realistic evaluation of the efficiencies of implementation of Best Management Practices on a particular farm.

The prioritization of farms for subsidies is complex and the creation of a methodology based in literature is essential for the overall impact of policy. This study creates a simplified methodology for the State of Vermont that could be enhanced with statistical weighting and geographic network data from publically available sources.

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APPENDIX A: Farm Identifications used in Chapter #3

Farm ID Number	County	Acres Owned	Acres Rented	Total Acres	Production	Generations in Family	Age of Principal Operator (s)	Gender
1	Addison	100	0	100	Animal (Fiber)	1	55	F
2	Addison	101.2	173.2	274.4	Meat	1	35	M
3	Washington	0	0	0	Meat	1	61, 58	M, F
4	Rutland	306	0	306	Meat	1	69	F
5	Rutland	560	40	600	Maple	3	65, 60	M, F
6	Rutland	80	100	180	Maple	1	68, 67	M, F
7	Chittenden	49	25	74	Maple	1	50, 40	M, F
8	Addison	60	0	60	Maple	1	55	M
9	Rutland	25	0	25	Vegetable and Meat	2	67	M
10	Chittenden	80	170	250	Vegetable and Meat	2	49, 43	M, F
11	Franklin	14	0	14	Vegetable and Meat	2	38	M
12	Washington	7.5	0	7.5	Vegetable and Meat	1	30, 29	M, F
13	Franklin	10.10	0	10.10	Vegetable and Meat (Fiber)	1	56	F
14	Franklin	6	0	6	Vegetable and Meat	1	55, 57	M, F
15	Rutland	39	0	39	Vegetable	N/A	56	F
16	Washington	148	10	158	Vegetable	1	59	M
17	Addison	54	0	54	Vegetable	1	57	F
18	Franklin	0	10	10	Vegetable	1	53	F
19	Addison	280	0	280	Vegetable	1	65, 64	M, F
20	Rutland	39	5	44	Vegetable	1	36	M
21	Grand Isle	120	10	130	Vegetable	7	45	M
22	Rutland	0	1	1	Vegetable	1	23	F
23	Franklin	150	0	150	Vegetable	1	59, 58	M, F
24	Chittenden	0	125	125	Vegetable	8	36, 33	M, F

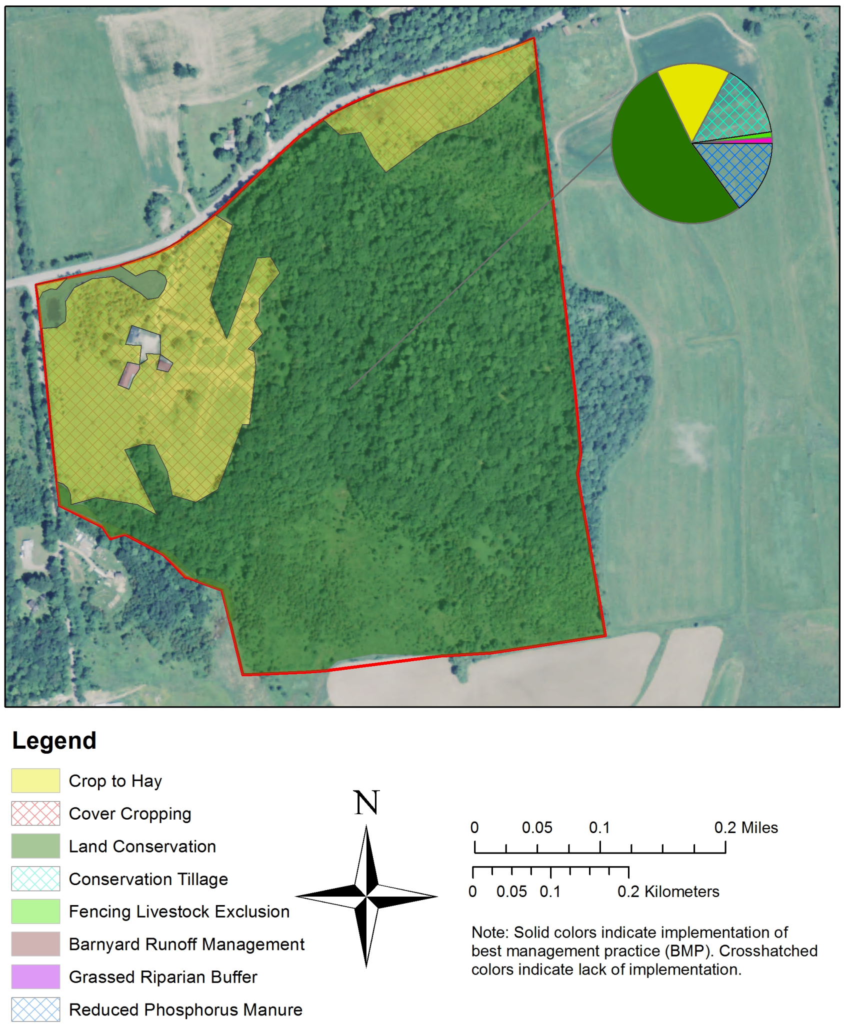
APPENDIX B: Farmer Identification used in Chapter #4

Farm ID Number	County	Acres Owned	Acres Rented	Total Acres	Production	Generations in Family	Age of Principal Operator (s)	Gender
1 (1)	Addison	100	0	100	Animal (Fiber)	1	55	F
2 (2)	Addison	101.2	173.2	274.4	Meat	1	35	M
3 (5)	Rutland	560	40	600	Maple	3	65, 60	M, F
4 (5)	Rutland	80	100	180	Maple	1	68, 67	M, F
5 (7)	Chittenden	49	25	74	Maple	1	50, 40	M, F
6 (9)	Rutland	25	0	25	Vegetable and Meat	2	67	M
7 (10)	Chittenden	80	170	250	Vegetable and Meat	2	49, 43	M, F
8 (12)	Washington	7.5	0	7.5	Vegetable and Meat	1	30, 29	M, F
9 (16)	Washington	148	10	158	Vegetable	1	59	M
10 (17)	Addison	54	0	54	Vegetable	1	57	F
11 (19)	Addison	280	0	280	Vegetable	1	65, 64	M, F
12 (20)	Rutland	39	5	44	Vegetable	1	36	M

Note. Farm Identification numbers in parentheses are from Chapter 3.

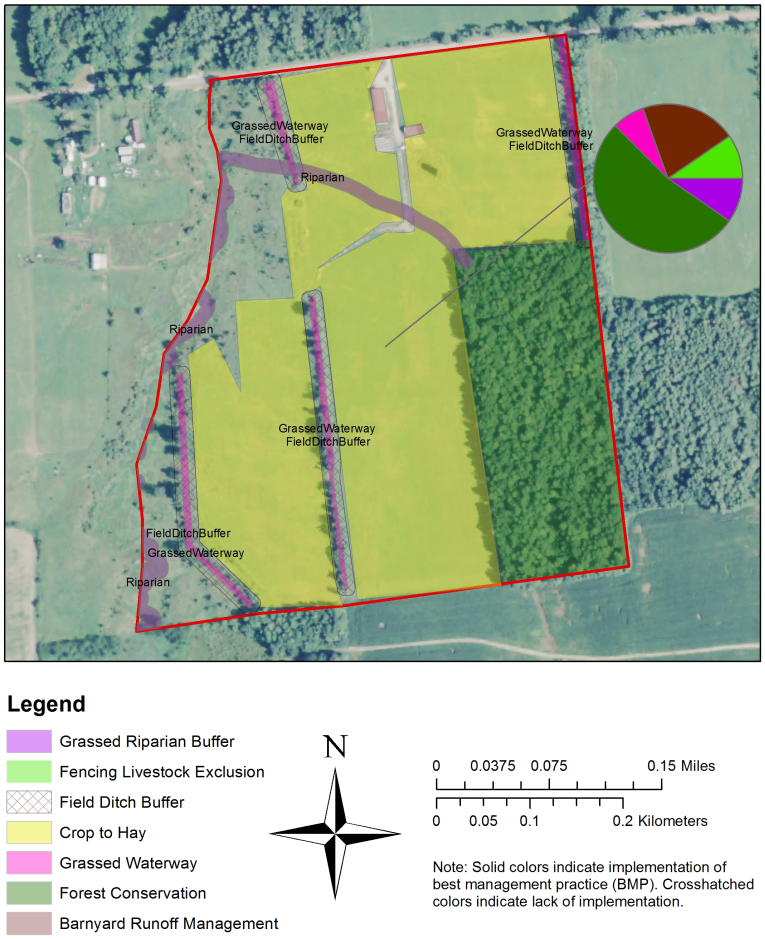
APPENDIX C: Spatial Representation of Best Management Practices on Farms

ID #1: Best Management Practices

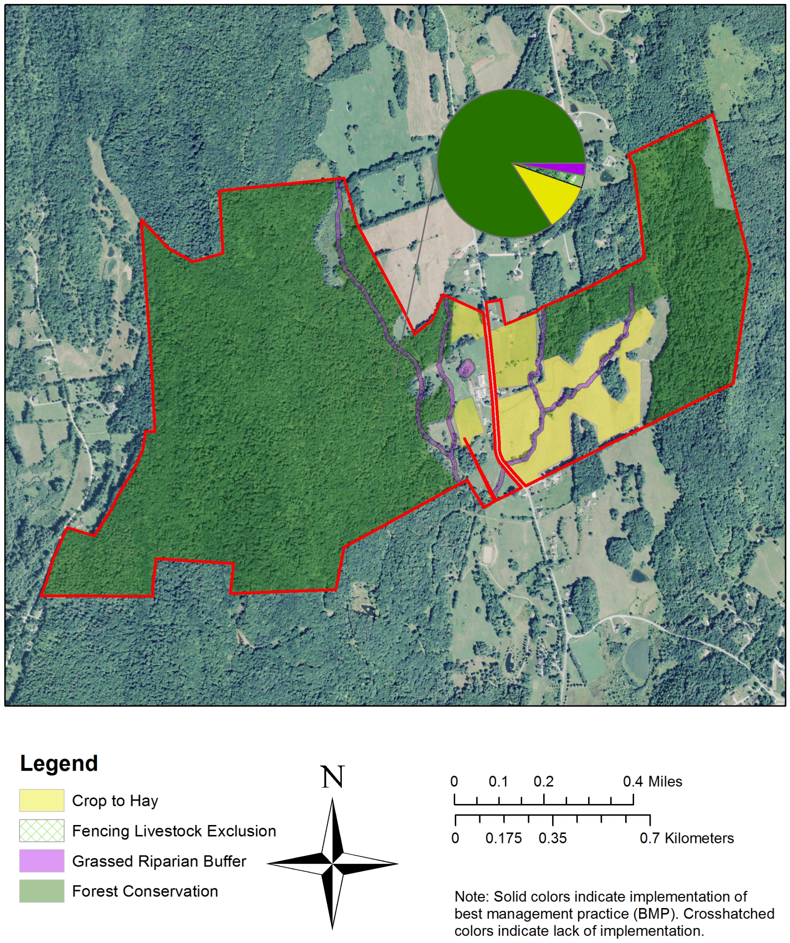


Note: Solid colors indicate implementation of best management practice (BMP). Crosshatched colors indicate lack of implementation.

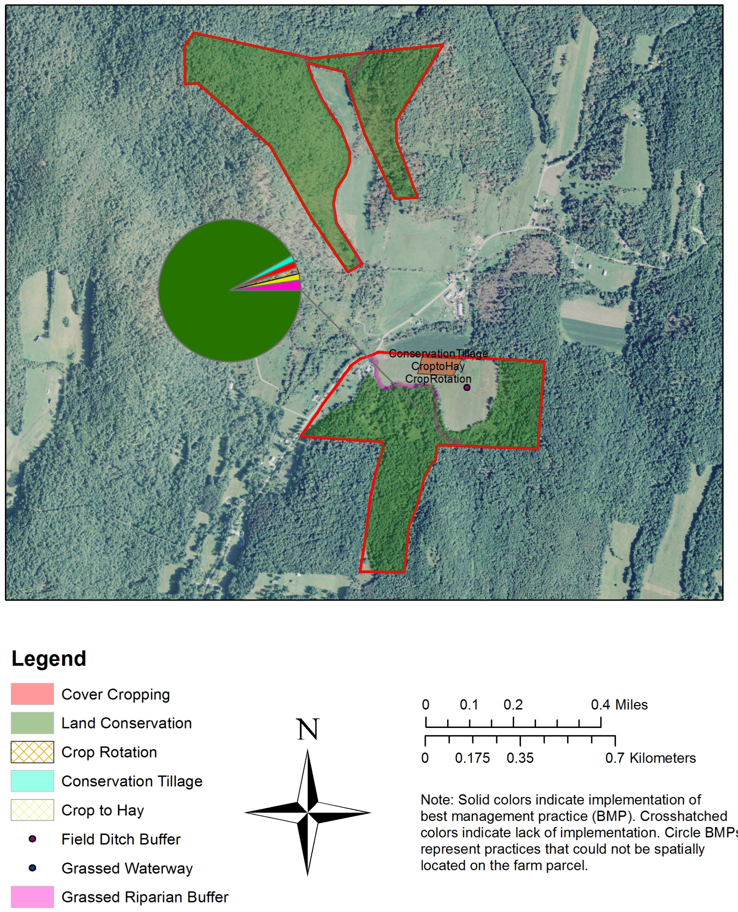
ID #2: Best Management Practices



ID #3: Best Management Practices



ID #4: Best Management Practices



ID #5: Best Management Practices

Legend

Land Conservation

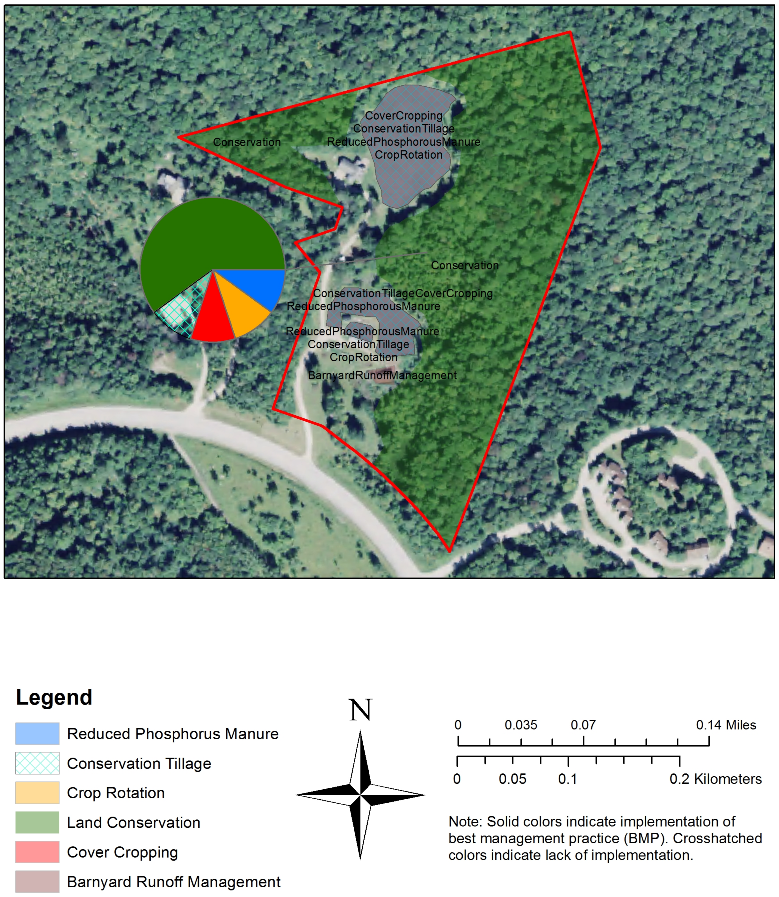
N

0 0.05 0.1 0.2 Miles

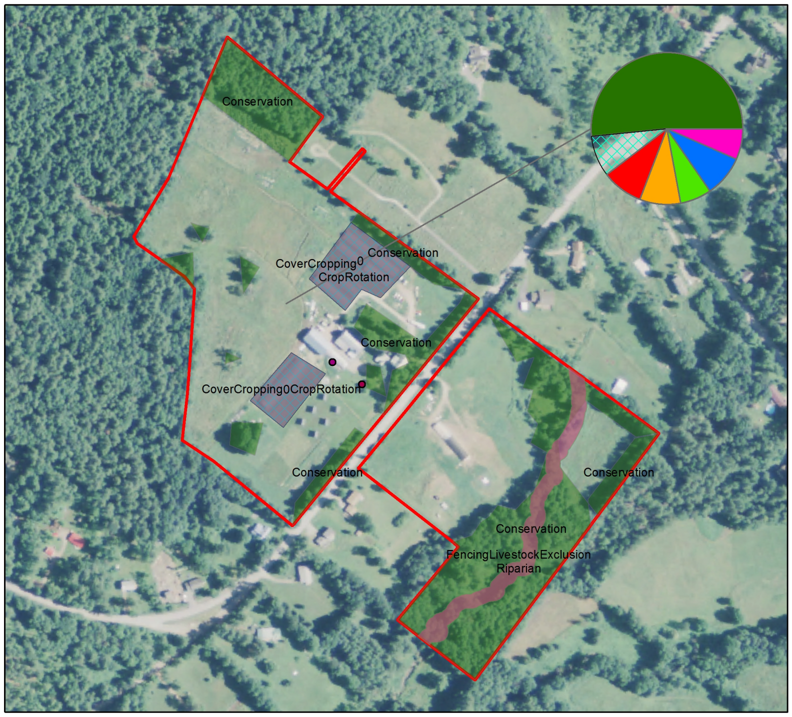
0 0.1 0.2 0.4 Kilometers

Note: Solid colors indicate implementation of best management practice (BMP). Crosshatched colors indicate lack of implementation.

ID #6: Best Management Practices



ID #7: Best Management Practices



Legend

- Grassed Waterway
- Field Ditch Buffer
- Reduced Phosphorus Manure
- Grassed Riparian Buffer
- Fencing Livestock Exclusion
- Conservation Tillage
- Crop Rotation
- Land Conservation
- Cover Cropping

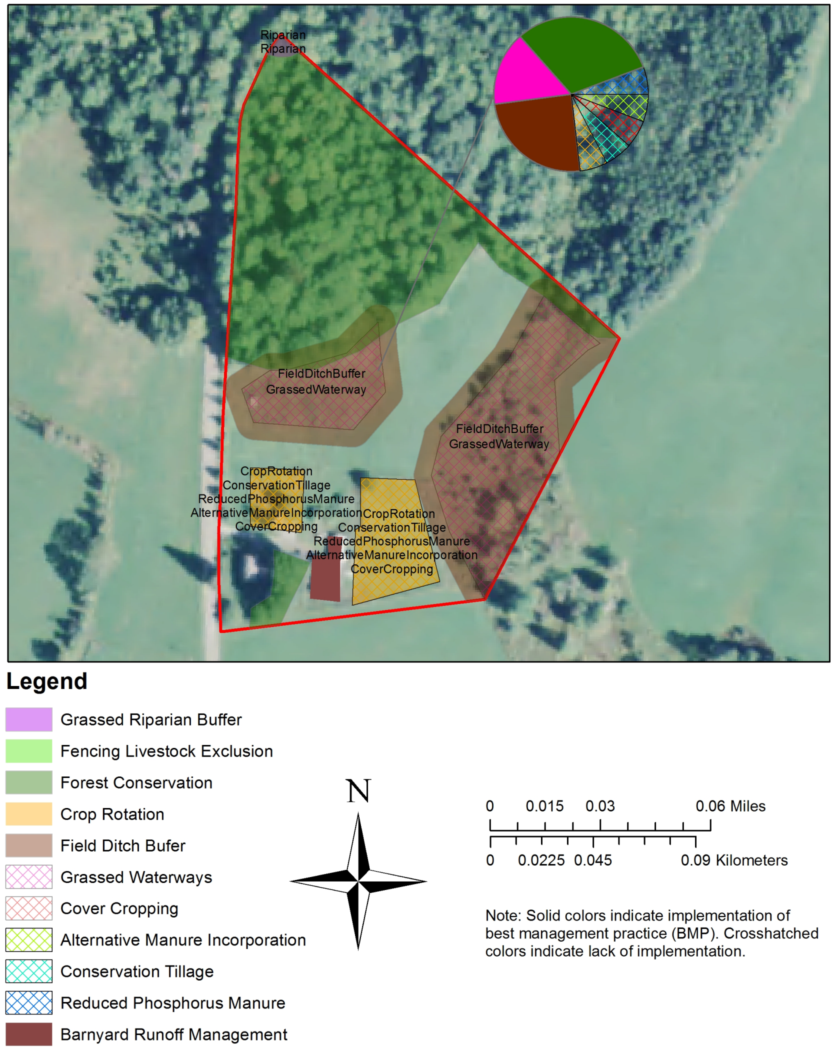
N

0 0.0375 0.075 0.15 Miles

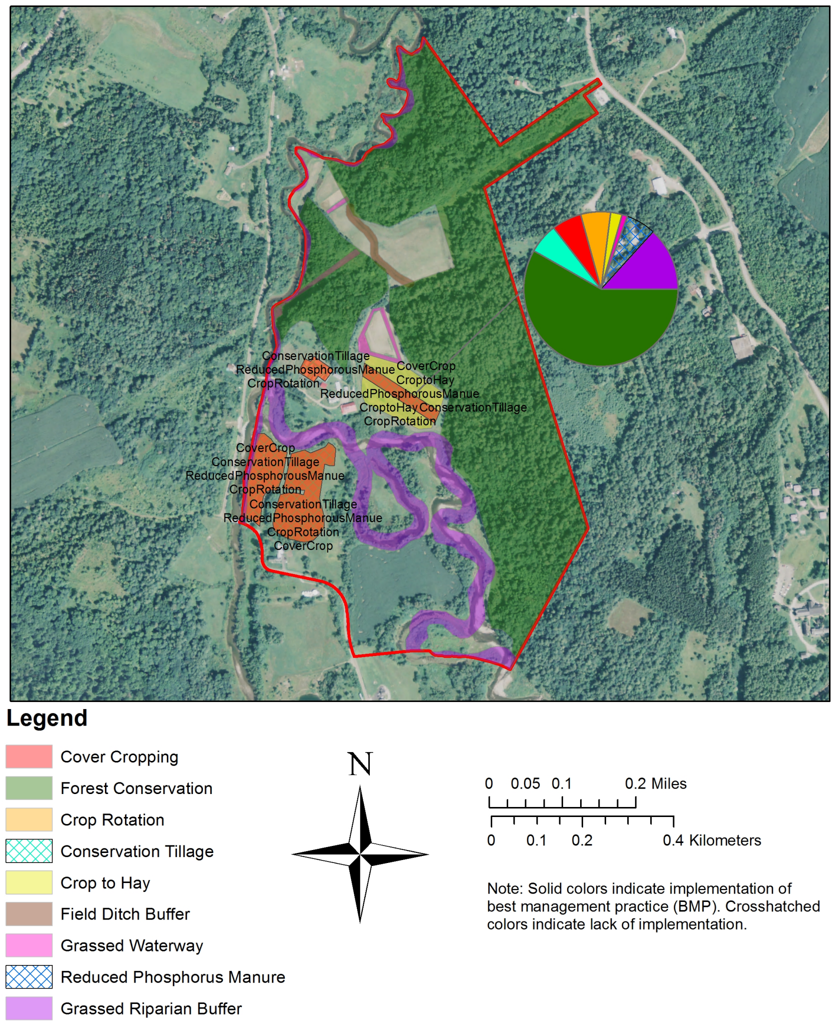
0 0.05 0.1 0.2 Kilometers

Note: Solid colors indicate implementation of best management practice (BMP). Crosshatched colors indicate lack of implementation. Circle BMPs represent practices that could not be spatially located on the farm parcel.

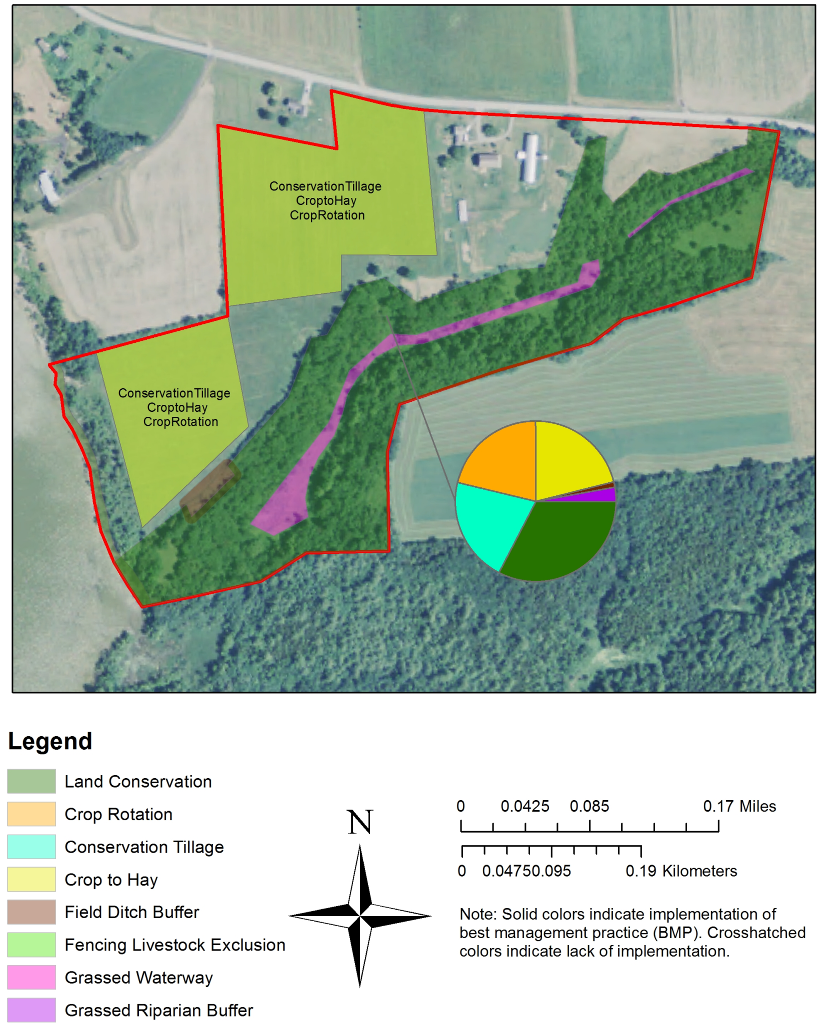
ID #8: Best Management Practices



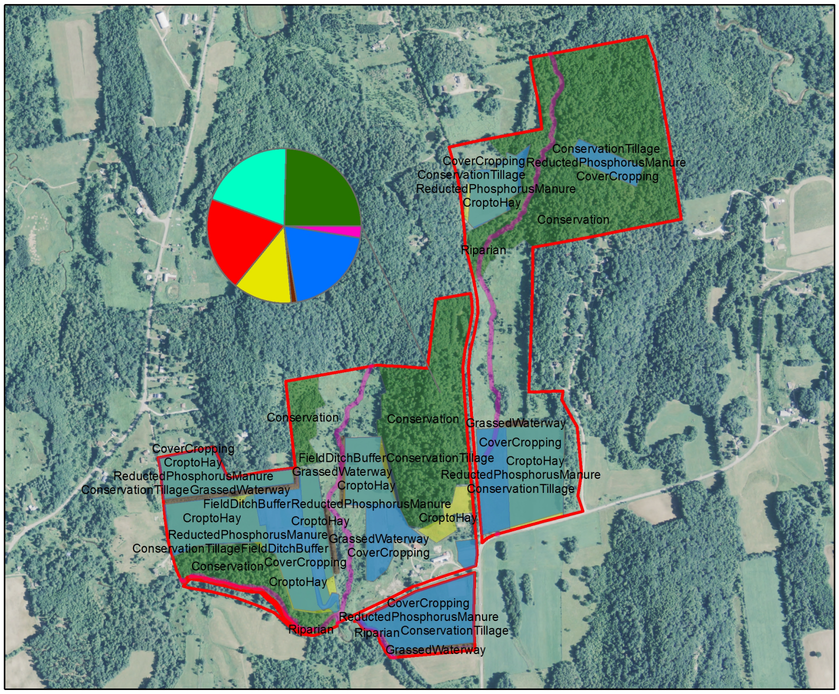
ID #9: Best Management Practices



ID #10: Best Management Practices



ID #11: Best Management Practices



Legend

- Reduced Phosphorus Manure
- Grassed Riparian Buffer
- Grassed Waterway
- Field Ditch Buffer
- Crop to Hay
- Conservation Tillage
- Land Conservation
- Cover Cropping

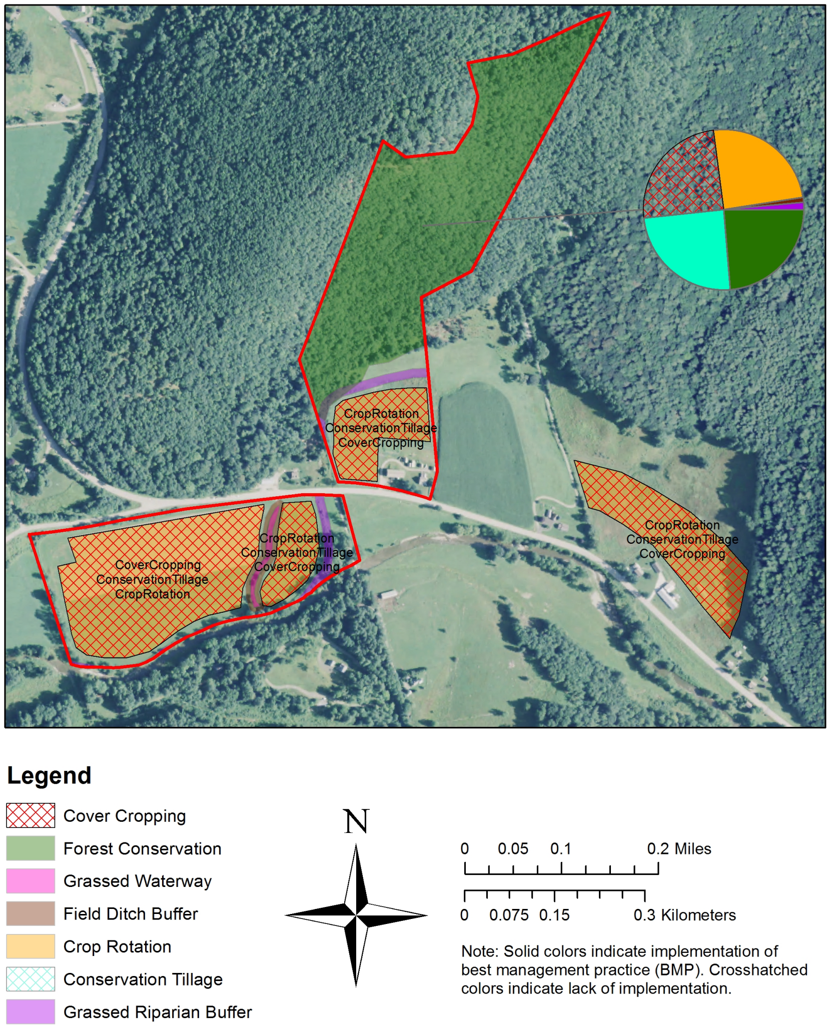
N

0 0.1 0.2 0.4 Miles

0 0.15 0.3 0.6 Kilometers

Note: Solid colors indicate implementation of best management practice (BMP). Crosshatched colors indicate lack of implementation.

ID #12: Best Management Practices



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